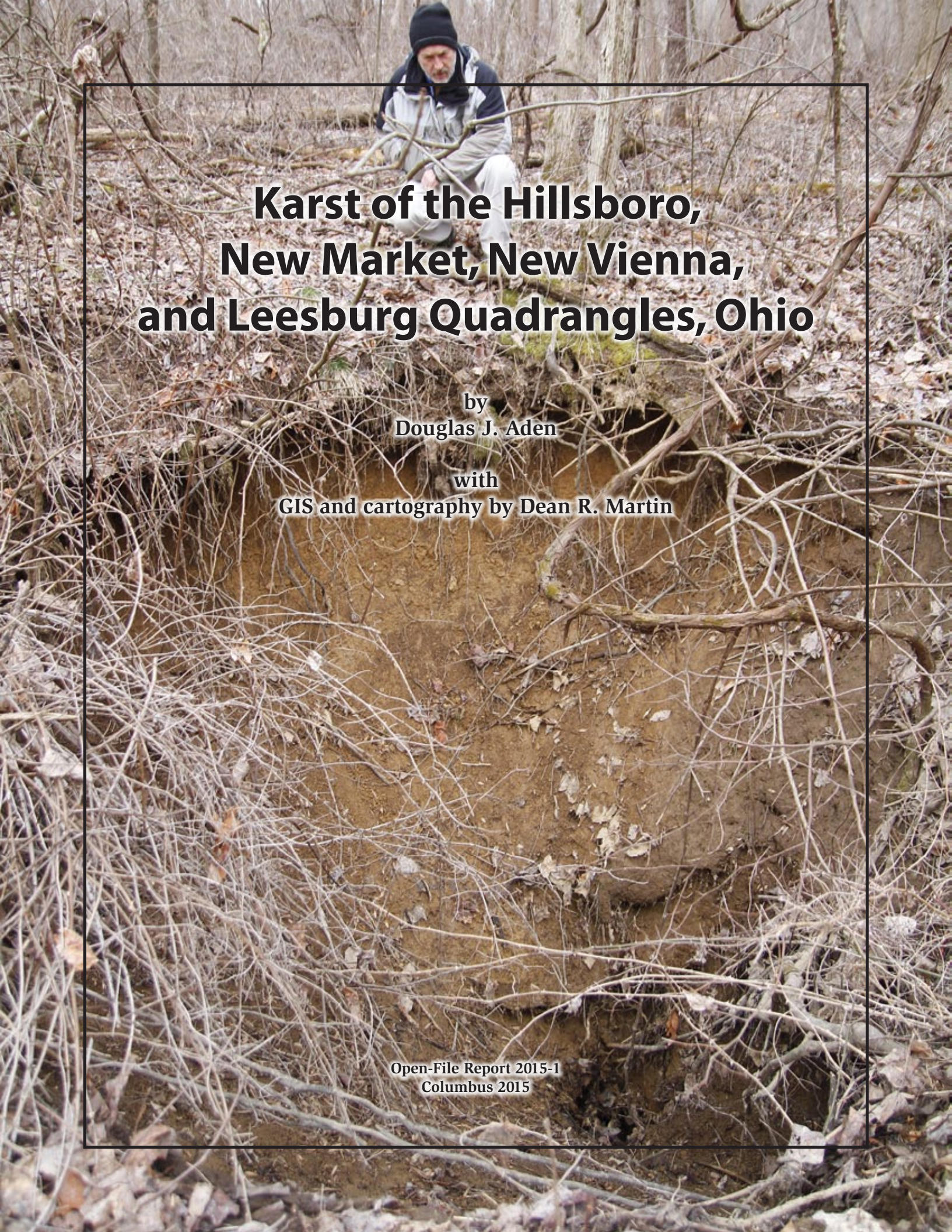

Karst of the Hillsboro, New Market, New Vienna, and Leesburg Quadrangles, Ohio

by
Douglas J. Aden

with
GIS and cartography by Dean R. Martin

Open-File Report 2015-1
Columbus 2015

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Cover image: At approximately 9 ft deep, this classically funnel-shaped sinkhole shows signs of recent collapse and has an open and active throat at the bottom; it was only 2 ft deep according to 2006 LiDAR data and has grown quickly since. The sinkhole is found within a much larger, older collapse that formed as two separate depressions merged. The larger sinkhole is 8 ft deep, 755 ft long, and 475 ft wide and irregularly shaped. This area is surrounded by trees and other plants, which will slow erosion and reduce further collapse. A large, active spring nearby runs brown with sediment after heavy rains, indicating connections to surface water and likely this sinkhole. An aerial view of this area is found on Tile 157.

Recommended citation: Aden, D.J., 2015, Karst of the Hillsboro, New Market, New Vienna, and Leesburg Quadrangles, Ohio: Columbus, Ohio Department of Natural Resources, Division of Geological Survey Open-File Report 2015-1, 4 p., 71 maps.

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by

Douglas J. Aden, with GIS and cartography by Dean R. Martin

Introduction

Karst terrain forms by dissolution of carbonate rocks, such as limestone or dolomite, or evaporites, such as gypsum or salt, and is characterized by features including sinkholes, disappearing streams, caves, and springs. *Sinkholes* (or *sinks*) are enclosed depressions that do not usually hold water; they often have a "throat" or opening at the bottom where they drain to the subsurface. When a stream flows into a sinkhole, it is known as a *disappearing stream* or *losing stream*. Water flowing into the ground can cause solution enlargement of natural fractures in the rock and eventually can grow into caves. The Ohio Revised Code defines a *cave* as "…a naturally occurring void, cavity, recess, or system of interconnecting passages beneath the surface of the earth or within a cliff or ledge…" (State of Ohio, 1989).

The many passageways formed in karst terrain allow for high connectivity between the land surface and the water table. These passageways permit water to bypass soil and rock layers that filter out contaminants. Consequently, when compounds such as fertilizers, pesticides, and waste enter sinkholes, they are rapidly transported to the water table and quickly pollute water wells, streams, and rivers. When water exits these solutional features, a *spring* is formed. Such springs enable release of these contaminants at the surface.

The different types of karst features may pose infrastructure complications; roads, utilities, houses, and other facilities built in karst areas are at risk of subsidence, collapse, or other damage. In order to provide a reference for future planning on both the local and regional scale, the Ohio Geological Survey has produced this map book identifying the known and suspected karst areas in the vicinity of Hillsboro, Ohio.

Previous Work

Karst areas have been studied in Ohio for many years. During the 1980s and 1990s, karst was researched for the proposed Superconducting Super Collider and was mapped statewide to determine areas suitable for storage of low-level nuclear byproducts. Ohio's preliminary map of karst features (Pavey and others, 1999) was completed in 1997 and released in 1999; it since has been updated with new data in 2003, 2005, and 2007 and will be updated again in the near future.

In the spring of 2008, severe karst-related flooding occurred in Bellevue and led to concern among residents of the area regarding Ohio's geologic hazards (Raab and others, 2009; Pavey and others, 2012). From 2011 to 2012, karst was mapped in the Delaware County region (Aden and others, 2011) and in the Springfield and Donnelsville 7.5-minute quadrangles (Aden, 2012). Next, from fall 2012 to spring 2014 karst was mapped in the Bellevue 7.5-minute quadrangle and parts of the Clyde and Castalia quadrangles (Aden, 2013) and the Fireside, Flat Rock, and the remaining portion of the Clyde quadrangle (Aden, 2014). With the majority of the northern and central karst areas complete, the Ohio Geological Survey shifted focus to southern Ohio. From fall 2014 to spring 2015, karst was mapped in the Hillsboro, New Market, New Vienna, and Leesburg quadrangles.

Methodology

A digital elevation map (DEM), generated from LiDAR (Light Detection and Ranging) data, was used to create a map layer that identified low, enclosed areas. To locate potential sinkholes, these low spots were cross referenced with known karst points, bedrock geology, aerial photography of multiple sources and ages, soil maps, glacial drift thickness maps, and water well logs. Suspect locations were then visited in the field, evaluated, and photographed. Through this process some of the LiDAR-derived depressions were found not to be sinkholes; features such as building foundations, broken field tiles, steep-walled streams, road culverts, and glacial features often produced enclosed areas similar in shape to sinkholes. Many of these misleading features were eliminated remotely

using both 6-inches-per-pixel aerial photography and experience from past field verification. However, many points remained that could not be distinguished remotely and these were visited in the field.

Results

The resulting karst feature data set was overlain on four different geologic data sets—the Land Surface, the Bedrock Geology, the Bedrock Topography, and the Drift Thickness maps—to show how the features are related to the local geology. The first of these is the Land Surface map (p. 5), which shows the 173 two-km² tiles and the 7.5-minute quadrangles that form the project area overlain on the DEM of the land surface. The Hillsboro quad was the core project area. However, three adjacent quads - New Market, New Vienna, and Leesburg - were mapped to define the edge of the karst region. The Land Surface map shows that in Hillsboro, sinks are concentrated near the break in slope at the tops of hills and often occur in clusters. One particularly unusual sinkhole was discovered in a cluster of 9 sinkholes—an 8 ft x 8ft square shaft formed in bedrock (exposed at the ground surface) approximately 20 ft deep with an additional 5-ft-deep fracture at bottom, likely indicating the presence of a cave. This sinkhole extends west for about another 10 ft with an additional deep, open collapse in soil. A strong directional trend (as was seen in the previous years' project [Aden, 2014]) was not observed in this project area at the 7.5-minute quadrangle scale; however, karst features do increase in frequency from north to south.

On the Land Surface map, tiles outlined in red contain the karst features identified through this project. No karst was identified in tiles outlined in black. In total, there are 644 karst features, including 42 springs, in 173 tiles. Note that the project area is restricted to the 7.5-minute quadrangle boundaries and not the tile boundaries (especially along the southern border). At the top left of each aerial imagery page (p. 9-74), a Tile Number references the corresponding numbered tile on the four overlay maps.

There are four types of karst features identified on each map:

- Red circles indicate field-verified features, i.e., those that have been visited in the field and confirmed as karst.
- Orange circles indicate sites that were visited but could not be verified at the time, for example a suspicious depression that is flooded or that lacks an active sink throat and cannot be clearly classified.
- Yellow circles represent areas with suspect characteristics, such as a subtle LiDAR depression, a location where access to the property could not be gained, or where there was not enough time to field check the point.
- Blue squares represent springs, where water was found flowing from the subsurface.

The next overlay map is the Bedrock Geology map (p. 6). This map shows that the karst features are forming primarily by dissolution of Silurian-age rocks, namely the Peebles, Lilley, and Bisher Dolomites. In the Hillsboro region, most well-developed karst is expressed as steep-walled, cone-shaped depressions with active sinking and an active sink throat where water drains. It should be noted that according to this map, there are sinks on shale, which indicates that either the shale is very thin and the sinks are forming through it, or the bedrock map needs to be refined. There are also springs located on shale; this is to be expected since water percolating down through vuggy limestone is impeded by shale and moves horizontally until it reaches the land surface.

Four hundred and thirty nine of the 644 karst features are within the Peebles Dolomite, Lilley Formation, and Bisher Formation undivided (**Splb** on the Bedrock Geology map) and 179 are within the Tymochtee Dolomite, Greenfield Dolomite, Peebles Dolomite, Lilley Formation, and Bisher Formation undivided (**St-b**).The 26 remaining points are comprised mostly of springs within the Estill Shale (**Se**) and a few sinkholes in the Greenfield Dolomite (**Sg**). These formations and the others on the Bedrock Geology map are buried in many places by surficial glacial materials. The elevation of the bedrock below the surficial materials is called Bedrock Topography and is shown on page 7. The elevations of the bedrock surface were subtracted from the DEM (p. 5) to create the Drift Thickness map (p. 8). Knowing the drift thickness is useful because where the drift is shallow—about 25 ft or less—sinkholes are commonly expressed. Other sinkholes may exist but were either buried beneath the glacial drift or prevented from forming by thick drift. The Drift Thickness map clearly shows that in the Hillsboro area, the sinkholes are concentrated along areas of thin glacial drift.

Following the four overlay maps are the detailed

two-km² map tiles (p. 9-74) that contain specific point locations. Also included on these maps are karst depressions represented by yellow to red topographic lines. Each concentric ring represents a one-foot drop in elevation toward the low point of an internally drained area.

Conclusions

Of the 644 mapped karst features, 424 have photos (from multiple angles for interesting features) and 402 appear on the LiDAR-derived sink layer. Many springs were located in this area and are generally found associated with clusters of sinkholes (see tiles 111, 114, 116, 124, 126, 132, 137, 157, 160, 168, and 172). Springs do not typically show up as depressions unless a catch basin was built and subsequently failed, thus many were located during field work by spotting springhouses. The large number of sinks found without LiDAR attests to the need for spending time in the field near known karst areas, looking for new features, and talking to the public. For example, 35 of 88 features in tile 172 and 20 of 45 features in the cluster on tile 160 were not located via the LiDAR. Farmers and other land holders are still one of the best sources of local information, particularly for historical features, such as drained ponds, old mill races, and even sinkholes that have been periodically or historically filled in.

In addition to this map book, a DVD containing the GIS data, metadata, LiDAR depressions, and photographs of many of the features is available. The GIS data contains details such as the location of each point and a brief description of what was found there. The metadata provides information on the sources and quality of the data used in this project. The LiDAR depressions layer records the depths and areas for many of the sinkholes. In addition, the collection of photographs captured for many of these features can be used to monitor the growth of preexisting sinkholes and development of new karst features, as well as assisting in identification. Identification is important because karst regions are highly susceptible to pollution and structures built near them may subside. The maps in this report will allow areas of land development near karst features to be better planned and maintained.

Acknowledgments

This project was funded by the Great Lakes Geologic Mapping Coalition surficial mapping grant program.

References Cited

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Aden, D.J., 2013 Karst of the Bellevue Quadrangle and portions of the Clyde and Castalia Quadrangles, Ohio: Ohio Department of Natural Resources, Division of Geological Survey Open-File Report 2013-1, 4p., 59 maps, accessible at < http://geosurvey.ohiodnr.gov/portals/geosurvey/PDFs/OpenFileReports/OFR_2013-1.pdf > .

Aden, D.J., 2014, Karst of the Fireside Quadrangle and portions of the Flat Rock and Clyde Quadrangles, Ohio: Ohio Department of Natural Resources, Division of Geological Survey Open-File Report 2014-1, 4 p., 42 maps, accessible at < http://geosurvey.ohiodnr.gov/portals/geosurvey/PDFs/OpenFileReports/OFR_2014-1.pdf > .

Aden, D.J., Powers, D.M., Pavey, R.R., Jones, D.M., Martin, D.R., Shrake, D.L., and Angle, M.P., 2011, Karst of the western Delaware County, Ohio, region: Ohio Department of Natural Resources, Division of Geological Survey Open-File Report 2011-4, 2 p., 35 maps, accessible at < http://geosurvey.ohiodnr.gov/portals/geosurvey/PDFs/OpenFileReports/OFR_2011-4.pdf > .

Pavey, R.R., Angle, M.P., Powers, D.M., Swinford, E.M., 2012, Karst flooding in Bellevue, Ohio, and vicinity—2008: Ohio Department of Natural Resources, Division of Geological Survey Map EG-5, scale 1:24,000, accessible at < http://geosurvey.ohiodnr.gov/digital-map-series-pgs/eg-5-map-of-bellevue-ohio-karst-flooding-2008 > .

Pavey, R.R., Hull, D.N., Brockman, C.S., Schumacher, G.A., Stith, D.A., Swinford, E.M., Sole, T.L., Vorbau, K.E., Kallini, K.D., Evans, E.E., Slucher, E.R., and Van Horn, R.G., 1999, Known and probable karst in Ohio: Ohio Department of Natural Resources, Division of Geological Survey Map EG-1, scale 1:500,000. [Revised 2002, 2004, 2007.]

Raab, James, Haiker, Bill, Jones, Wayne, Angle, Michael, Pavey, Rick, Swinford, Mac, and Powers, Donovan, 2009, Ground water induced flooding in the Bellevue, Ohio area, spring and summer 2008:

Ohio Department of Natural Resources, Division of Water Technical Report of Investigation 2009-1, 19 p., accessible at < http://geosurvey.ohiodnr.gov/portals/geosurvey/PDFs/Karst/Bellevue_Final_Report.pdf > .

State of Ohio, 1989, Ohio Revised Code 1517.21 Cave definitions, in chap. 1517 of Title 15, Conservation of Natural Resources: State of Ohio, Ohio Revised Code, accessible at < http://codes.ohio.gov/orc/1517.21 > .

Further Reading

For more information on karst in Ohio, visit the Ohio Geological Survey website, **OhioGeology.com.** The following resources also provide additional information on karst and its effects in Ohio and beyond.

American Geological Institute

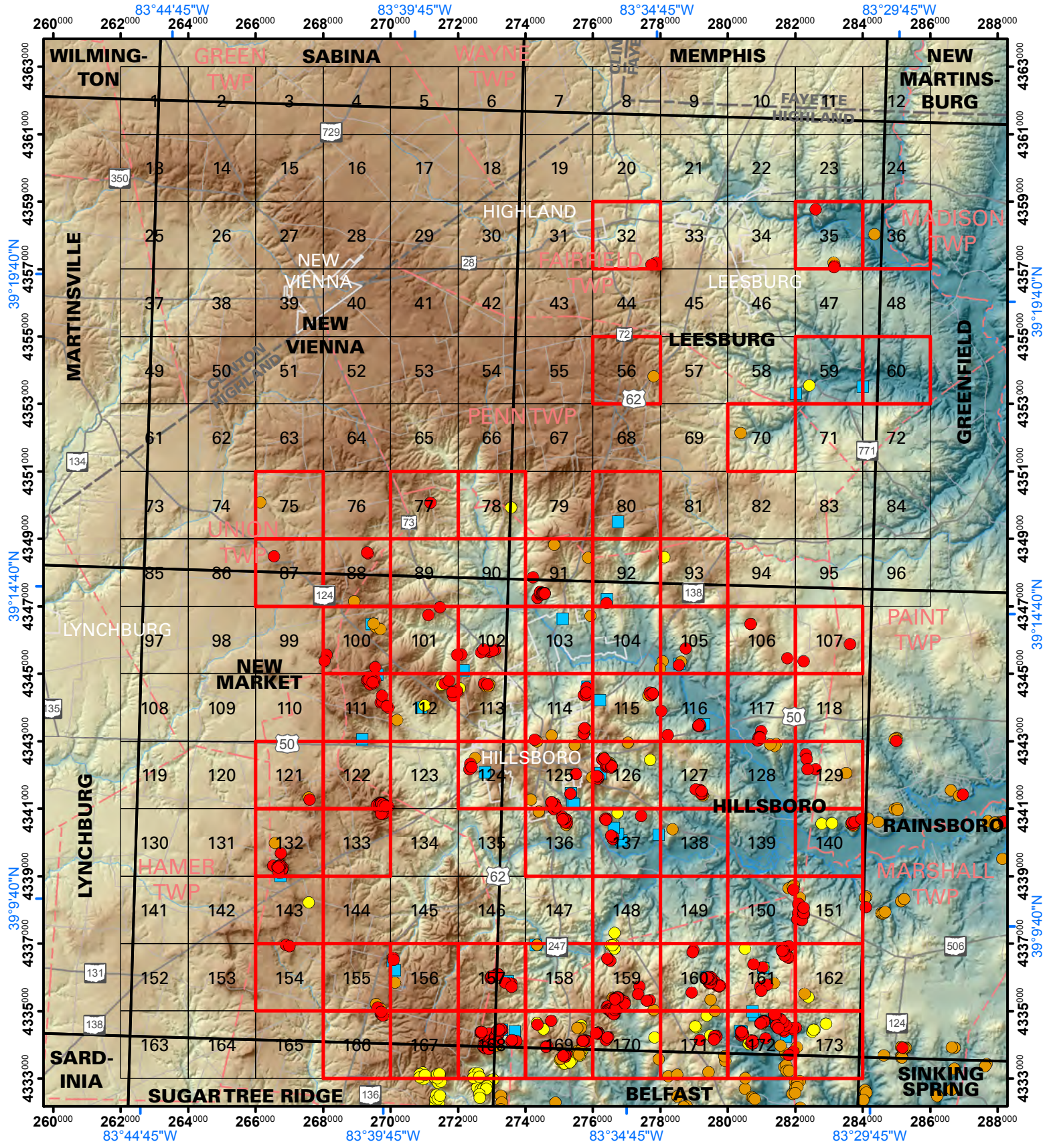
Living with Karst—A Fragile Foundation, AGI Environmental Awareness Series, no. 4, accessible at < http://www.agiweb.org/environment/publications/karst.pdf > .

National Speleological Society

Hobbs, H.H., III, 2009, The Glaciated Central Lowlands—Ohio, *in* Palmer, A.N., and Palmer, M.V., eds., Caves and Karst of the USA: National Speleological Society, p. 136–140.

U.S. Geological Survey

USGS Groundwater Information, Karst and the USGS, accessible at < http://water.usgs.gov/ogw/karst/ > .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83°39'45"W
83°34'45"W
83°29'45"W
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4341000
4339000
4337000
4335000
4333000
39°19'40"N
39°14'40"N
39°9'40"N
WILMING-TON
GREEN TWP
SABINA
WAYNE TWP
CLIN
FAYE
MEMPHIS
FAYETTE
HIGHLAND
NEW MARTINS-BURG
MARTINSVILLE
HIGHLAND
MADISON TWP
NEW VIENNA
FAIRFIELD TWP
LEESBURG
GREENFIELD
CLINTON HIGHLAND
PENN TWP
UNION TWP
LYNCHBURG
PAINT TWP
NEW MARKET
HILLSBORO
RAINSBORO
HAMER TWP
MARSHALL TWP
SARD-INIA
SUGARTREE RIDGE
BELFAST
SINKING SPRING
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72
62
771
134
73
124
138
135
50
62
247
506
131
138
124
136
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Tiles containing karst features
US National Grid
0
5 miles
0
5 kilometers
Scale 1:150,000
Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.
KARST FEATURES
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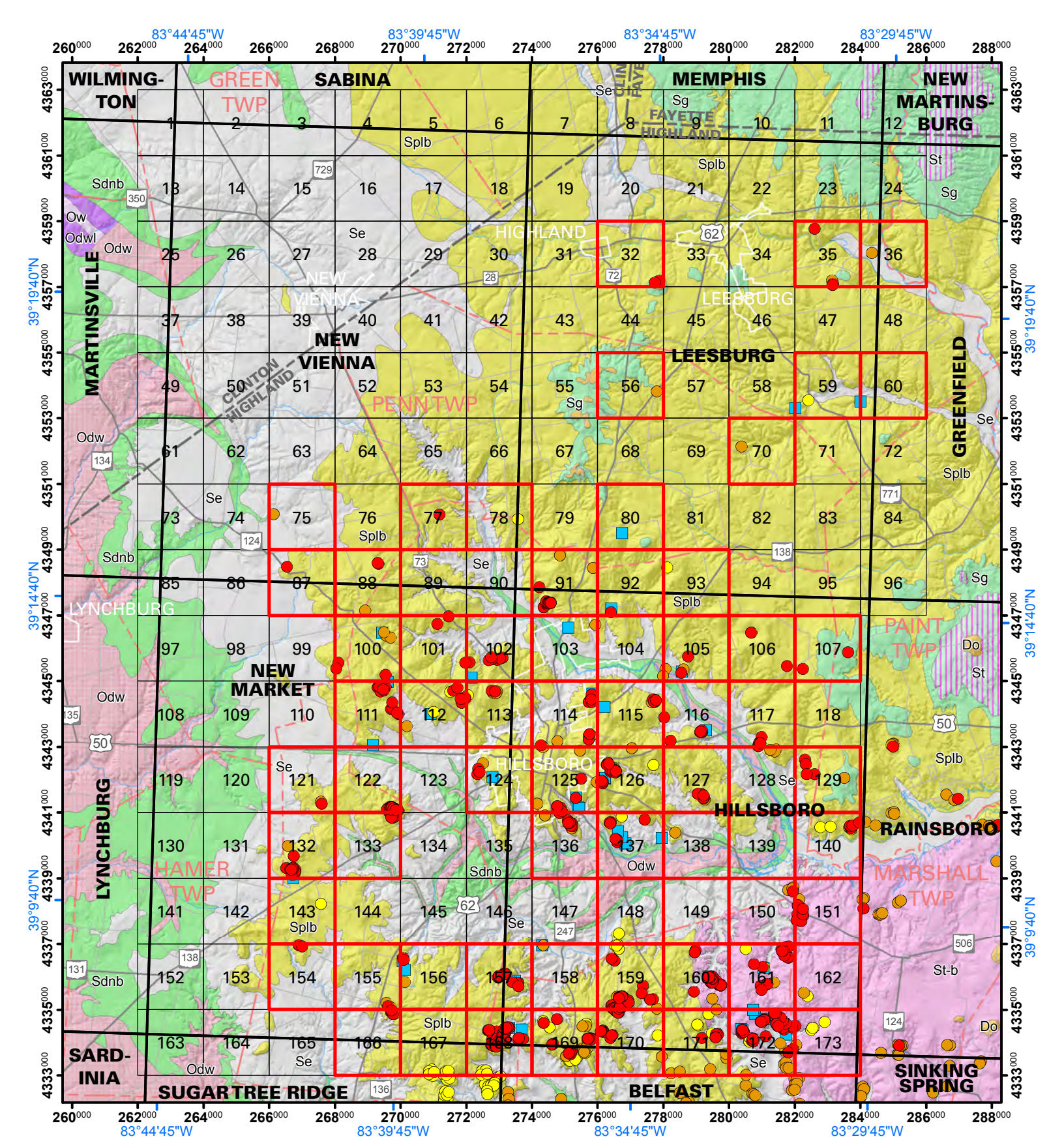
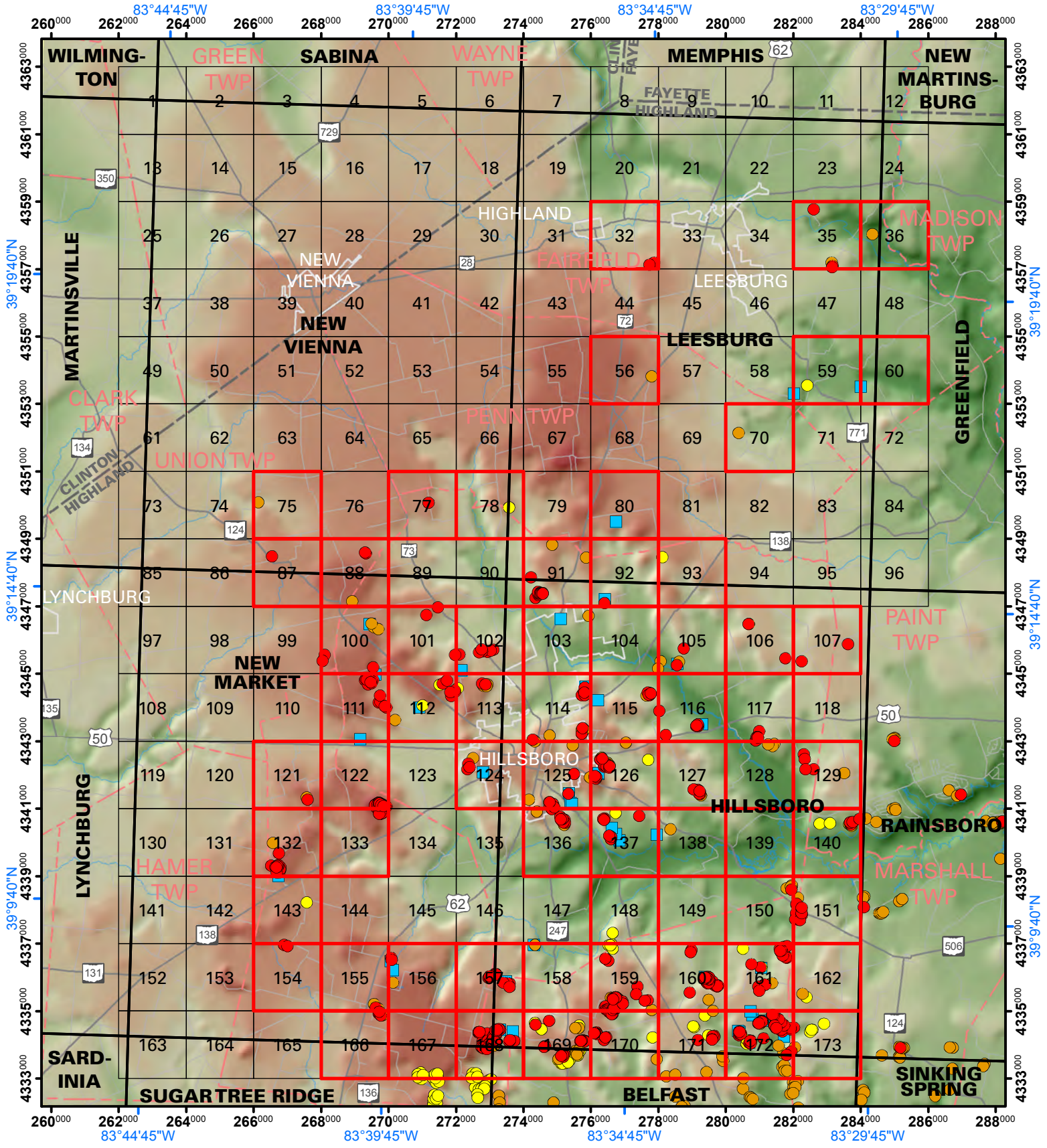
Suspect - field visited
Suspect - not visited
Spring
ELEVATION
in feet
High: 1,222
Low: 798


83°44'45"W
83°39'45"W
83°34'45"W
83°29'45"W
39°19'40"N
39°14'40"N
39°9'40"N
WILMING-TON
GREEN TWP
SABINA
MEMPHIS
NEW MARTINS-BURG
MARTINSVILLE
NEW VIENNA
LEESBURG
GREENFIELD
PENN TWP
LYNCHBURG
NEW MARKET
PAINT TWP
HILLSBORO
RAINSBORO
HAMER TWP
MARSHALL TWP
SARD-INIA
SUGARTREE RIDGE
BELFAST
SINKING SPRING
HIGHLAND
FAYETTE
CLINTON
Tiles containing karst features
US National Grid
0 5 miles
0 5 kilometers
Scale 1:150,000
Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.
KARST FEATURES
Field verified
Suspect - field visited
Suspect - not visited
Spring
BEDROCK GEOLOGY
Do Ohio and Olentangy Sh undivided
St Tymochtee Dol
Sg Greenfield Dol
Splb Peebles Dol, Lilley Fm, Bisher Fm undivided
St-b Tymochtee, Greenfield, & Peebles Dol, Lilley Fm, Bisher Fm undivided
Se Estill Sh
Sdnb Dayton Ls, Noland Fm, Brassfield Fm undivided
Odwl Drakes, Whitewater, & Liberty Fm undivided
Odw Drakes Fm & Waynesville Fm undivided
Ow Waynesville Fm



Tiles containing karst features

US National Grid

0 5 miles

0 5 kilometers

Scale 1:150,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

BEDROCK TOPOGRAPHY
Elevation in feet

High: 1,202

Low: 744

83°44'45"W
83°39'45"W
83°34'45"W
83°29'45"W
39°19'40"N
39°14'40"N
39°9'40"N
WILMING-TON
GREEN TWP
SABINA
WAYNE TWP
MEMPHIS
NEW MARTINS-BURG
MARTINSVILLE
HIGHLAND
MADISON TWP
FAIRFIELD TWP
NEW VIENNA
LEESBURG
GREENFIELD
CLINTON HIGHLAND
PENN TWP
LYNCHBURG
NEW MARKET
PAINT TWP
HILLSBORO
RAINSBORO
HAMER TWP
MARSHALL TWP
LYNCHBURG
SARD-INIA
SUGAR TREE RIDGE
BELFAST
SINKING SPRING
Tiles containing karst features
US National Grid
0
5 miles
0
5 kilometers
Scale 1:150,000
Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.
KARST FEATURES
Field verified
Suspect - field visited
Suspect - not visited
Spring
DRIFT THICKNESS
in feet
<25
25–50
50–100
>100

Tile Number: 32

US National Grid

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Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 35

US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

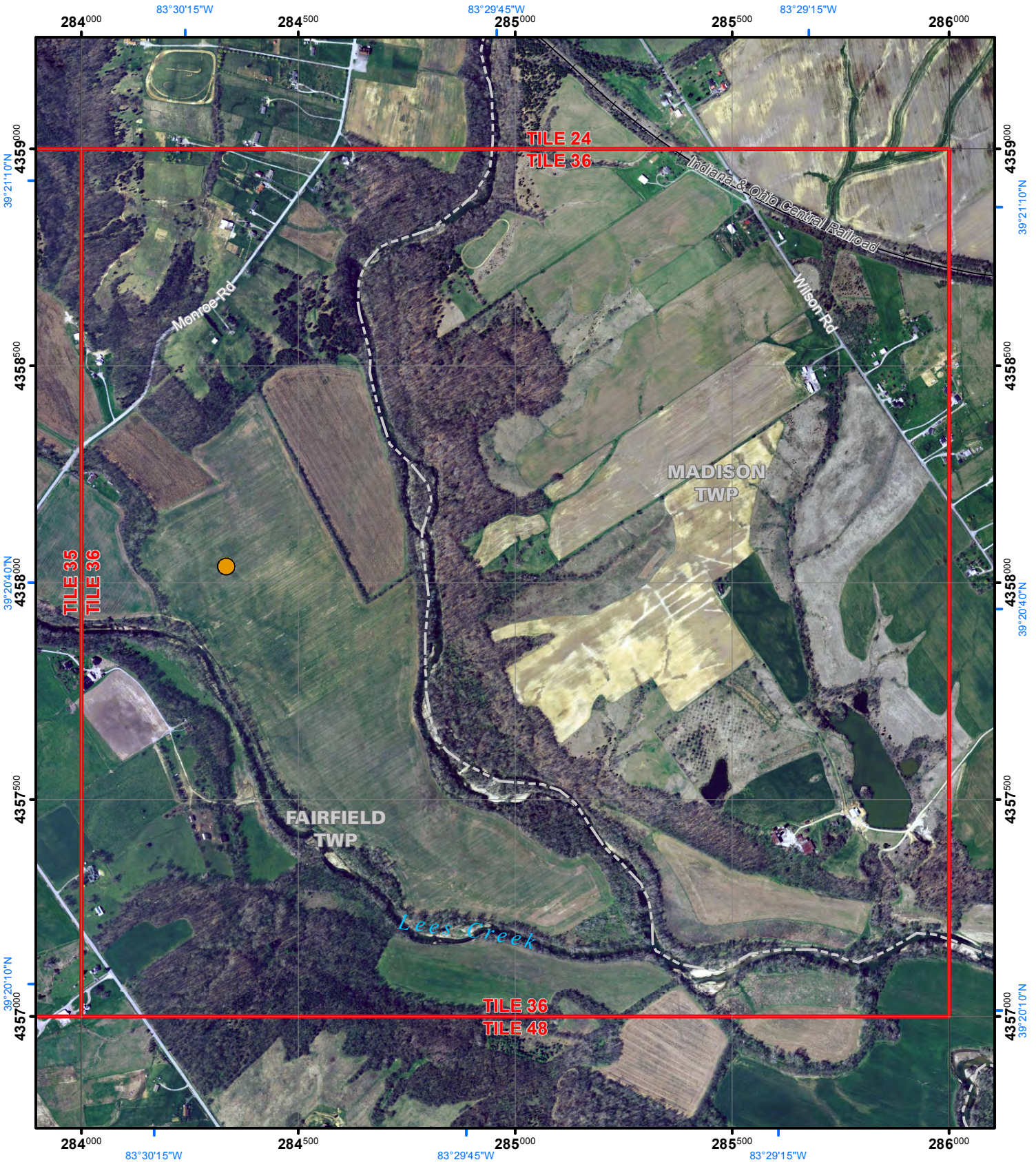
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 36



US National Grid

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0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

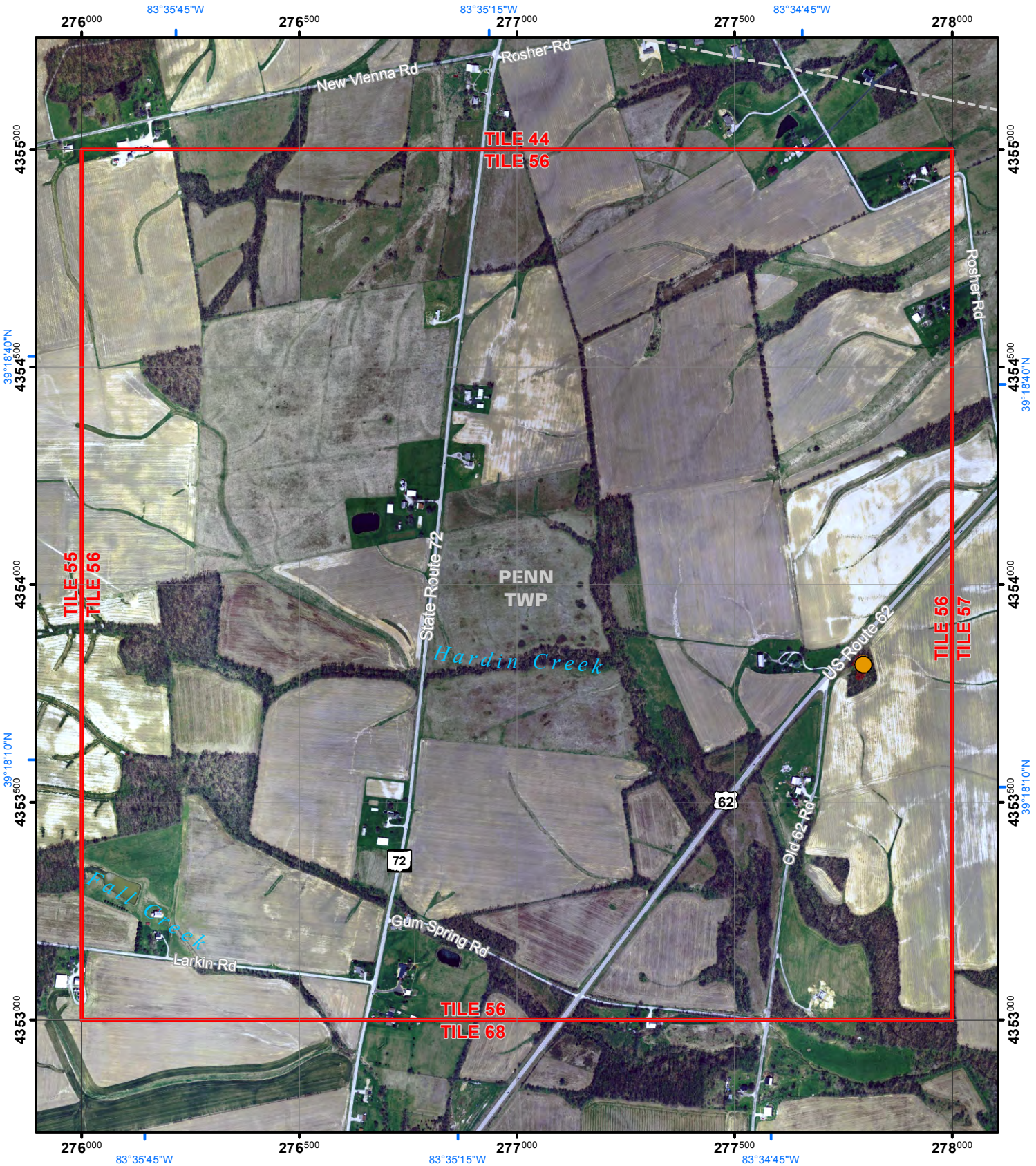
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 56



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Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

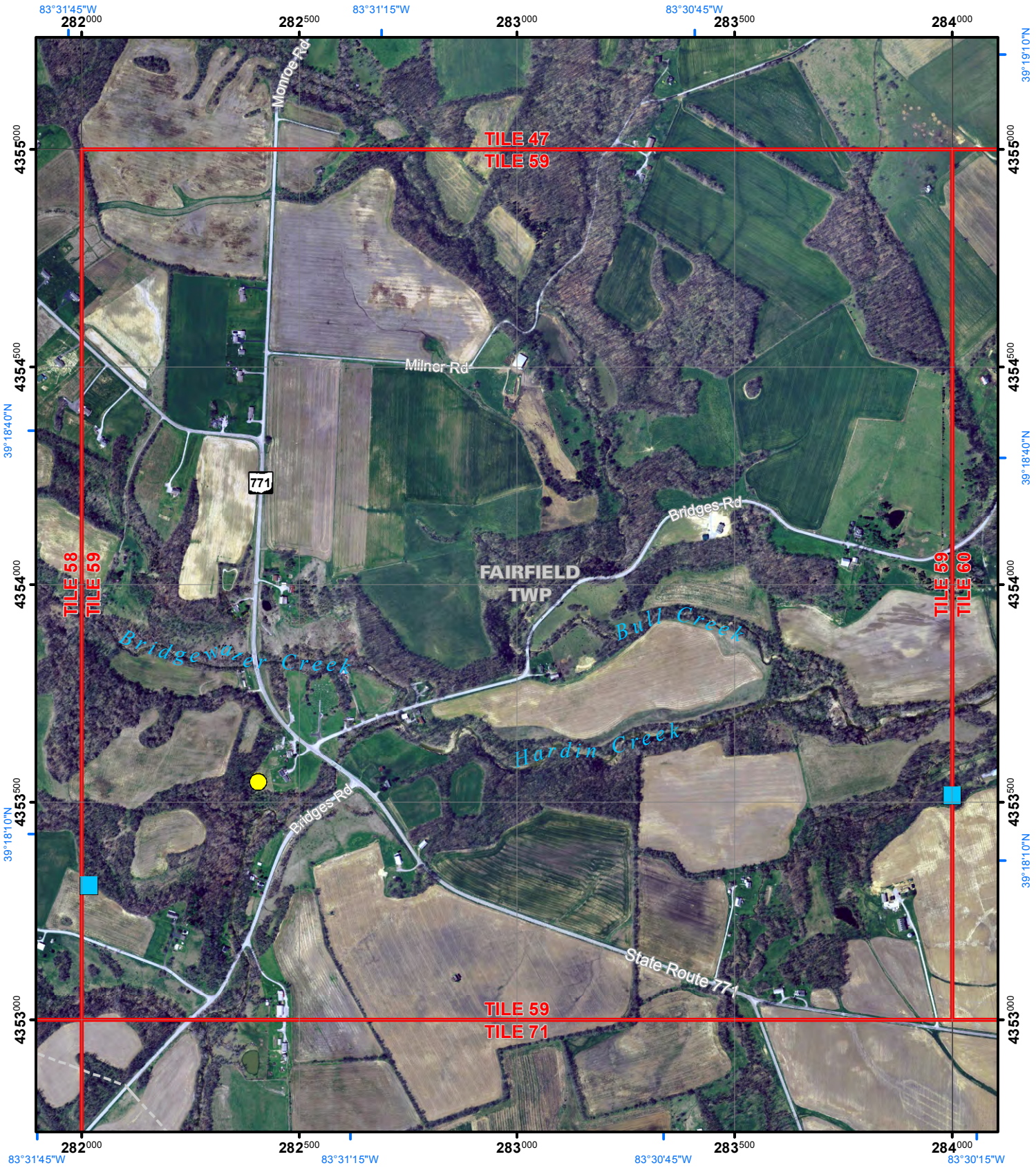
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 59



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

KARST FEATURES

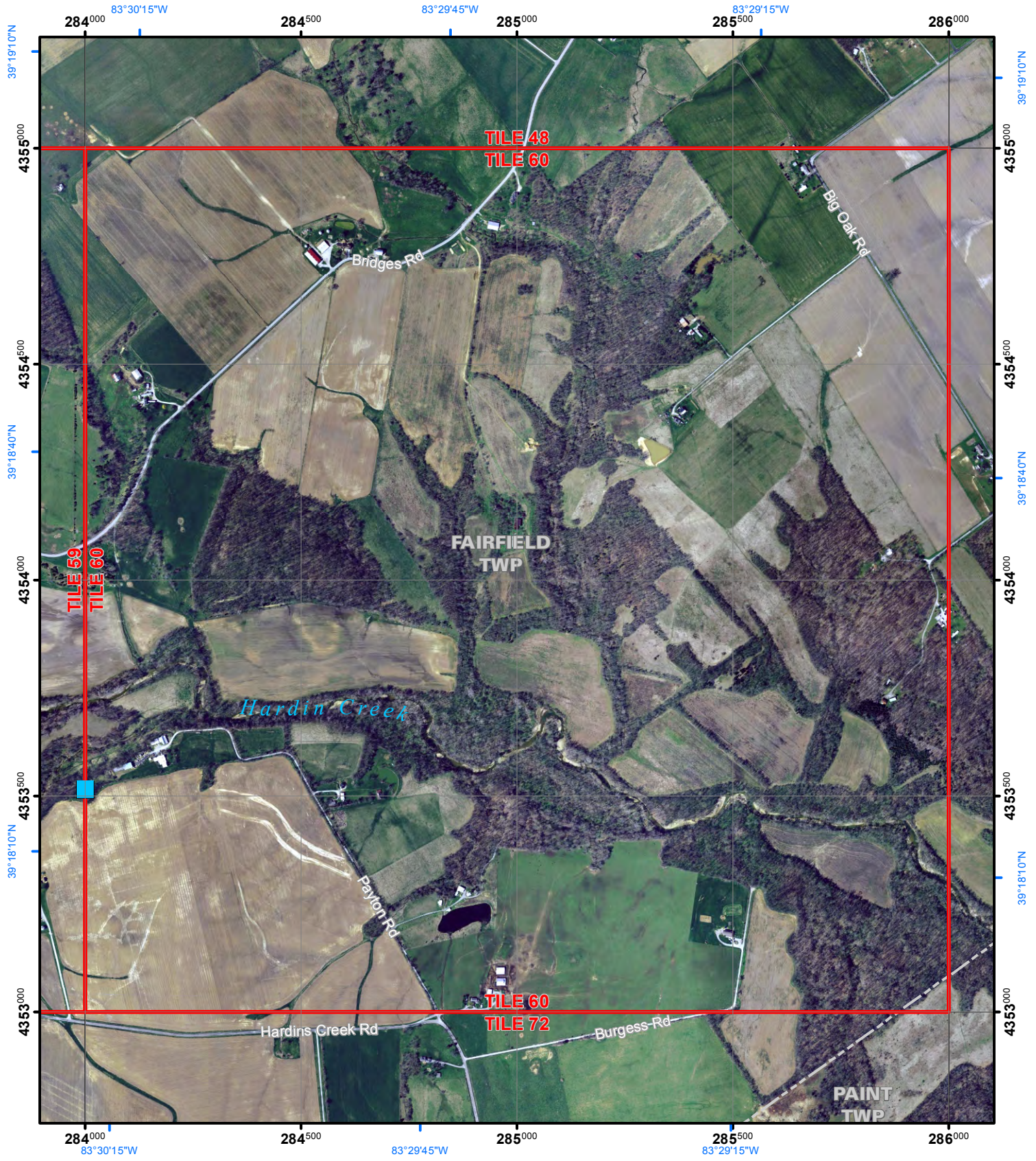
- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION

Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 60



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 70

US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 75

US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 77

US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

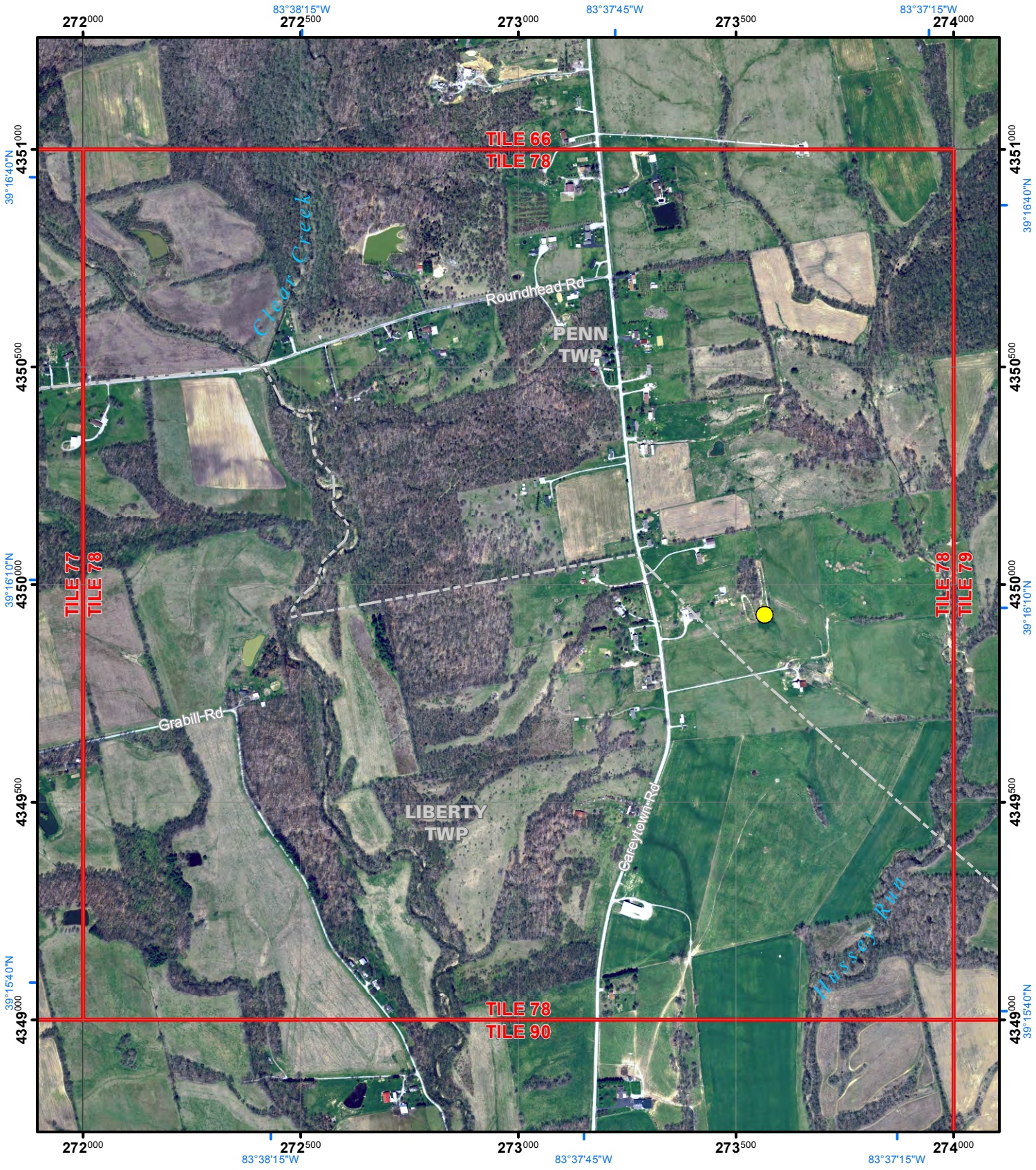
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 78



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

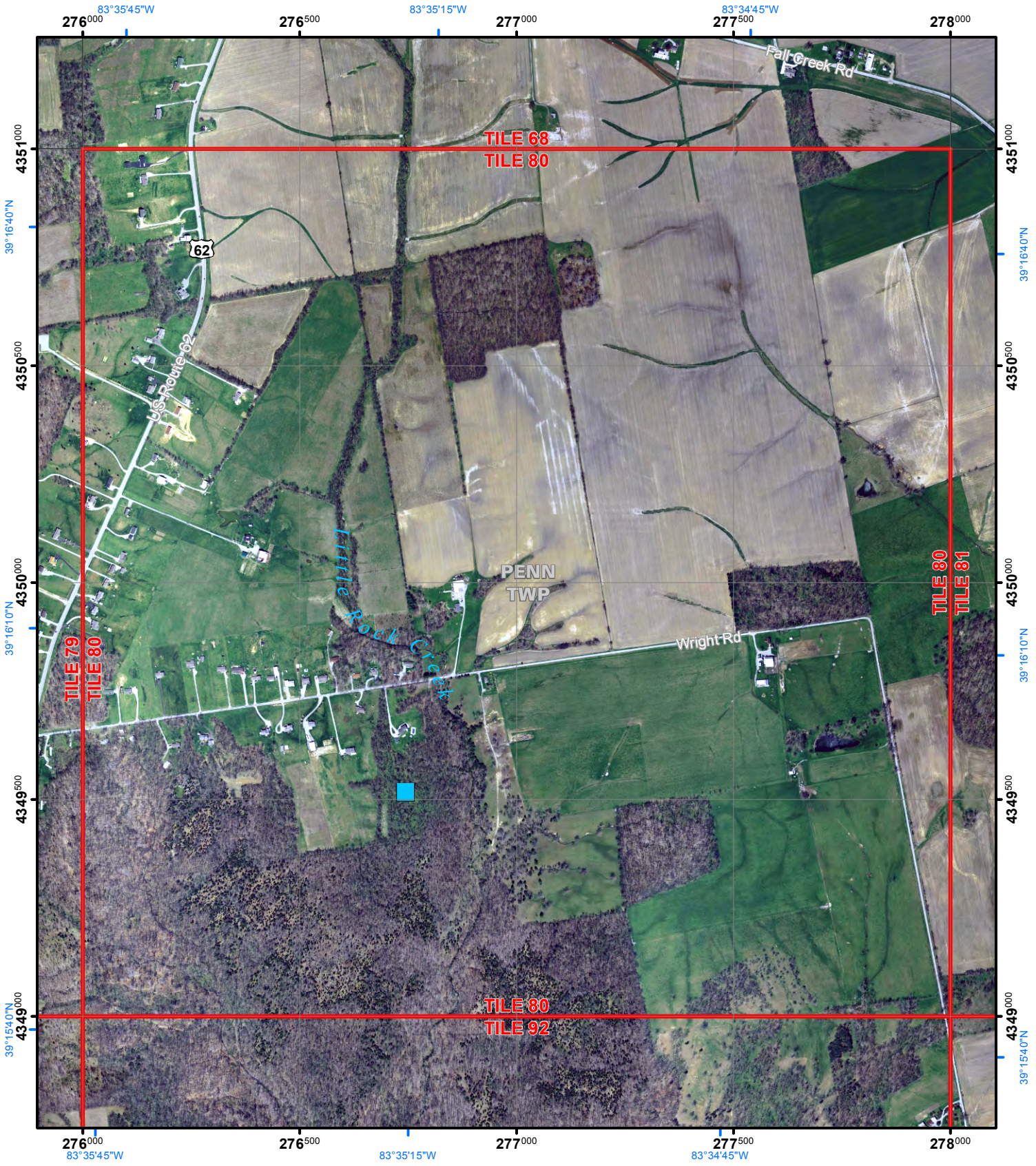
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 80



US National Grid

100,000-m Square ID: KD

Grid Zone Designation: 17S

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

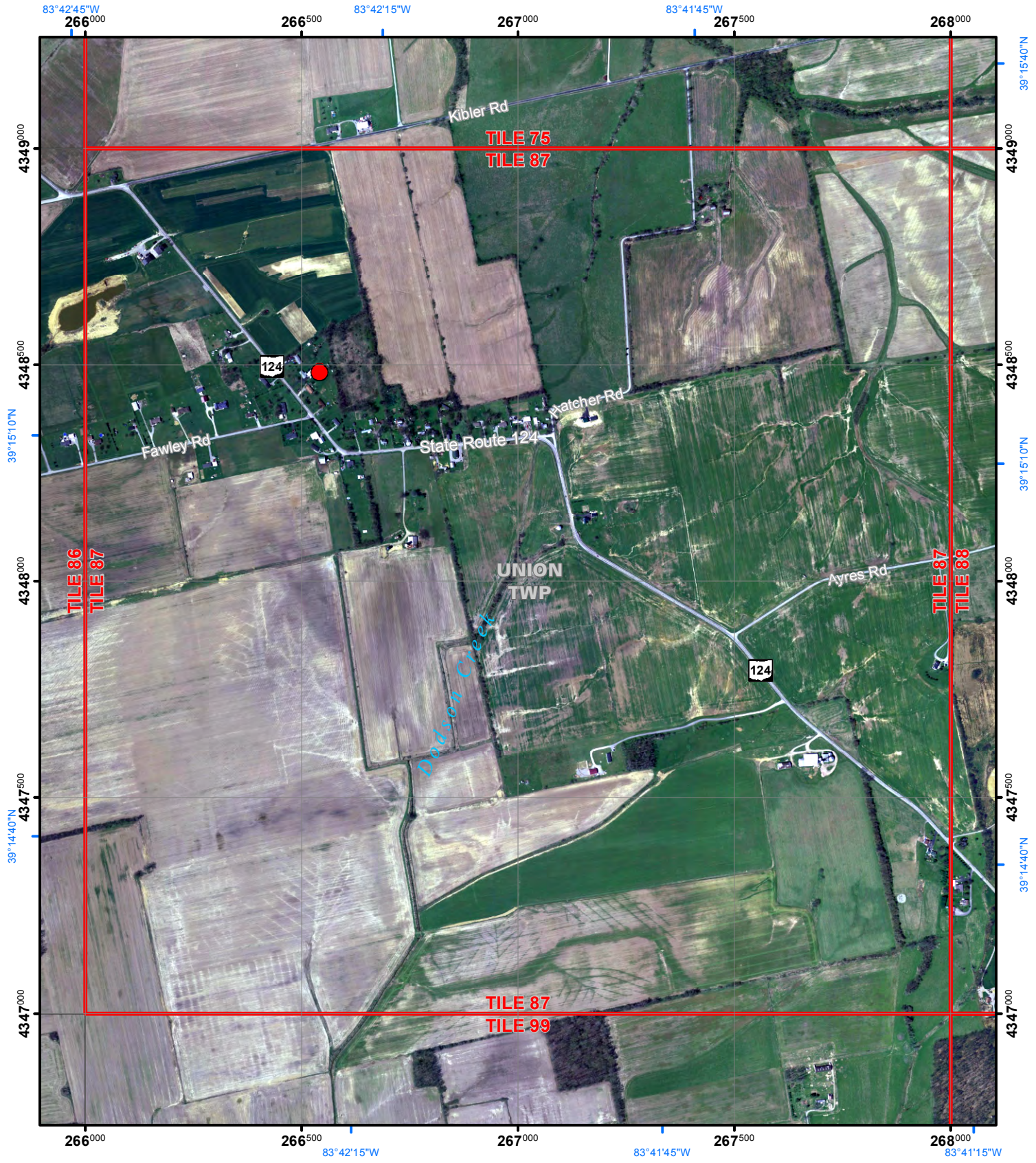
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 87



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

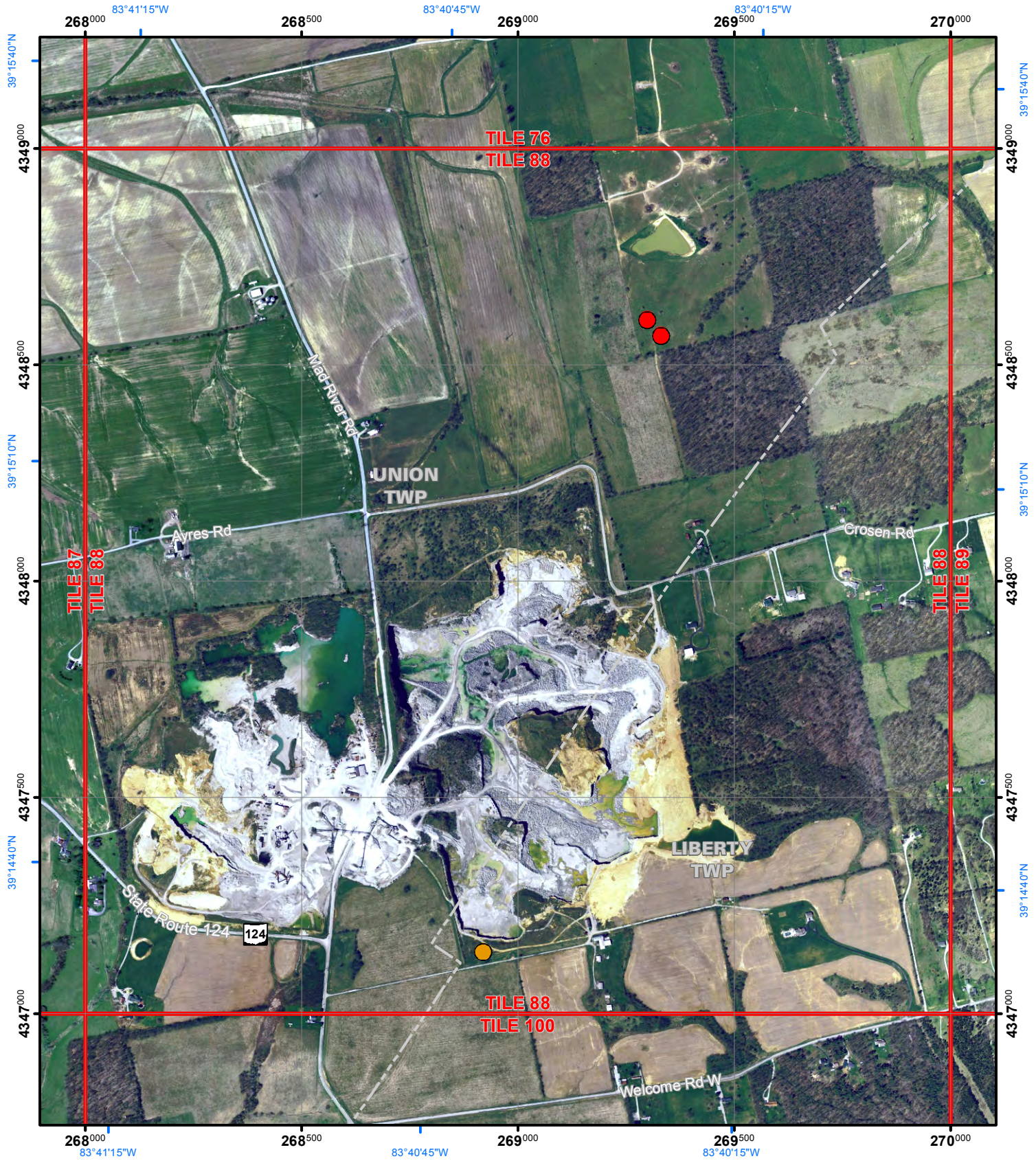
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 88



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

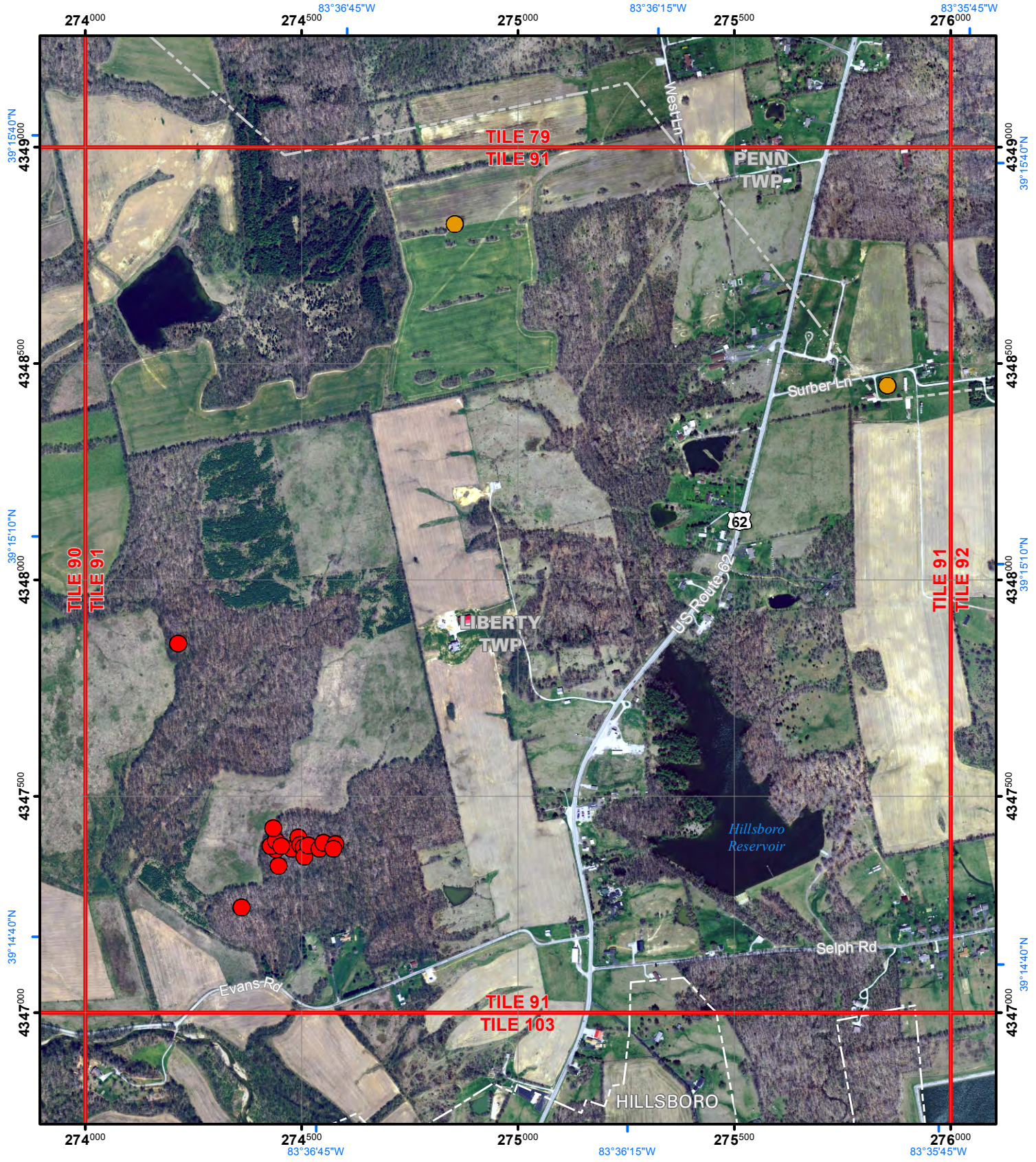
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 91



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

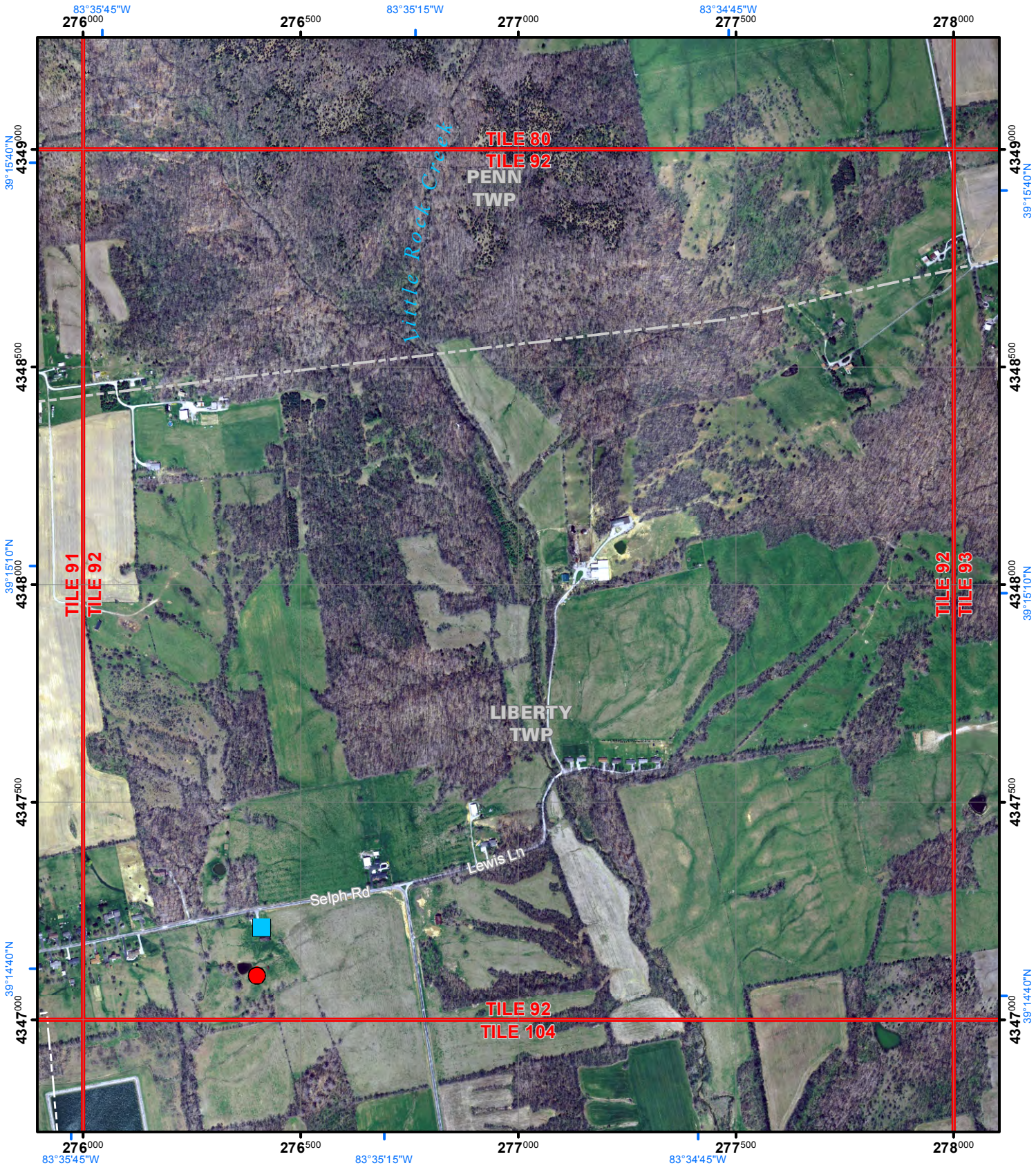
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 92



US National Grid

100,000-m Square ID: KD

Grid Zone Designation: 17S

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

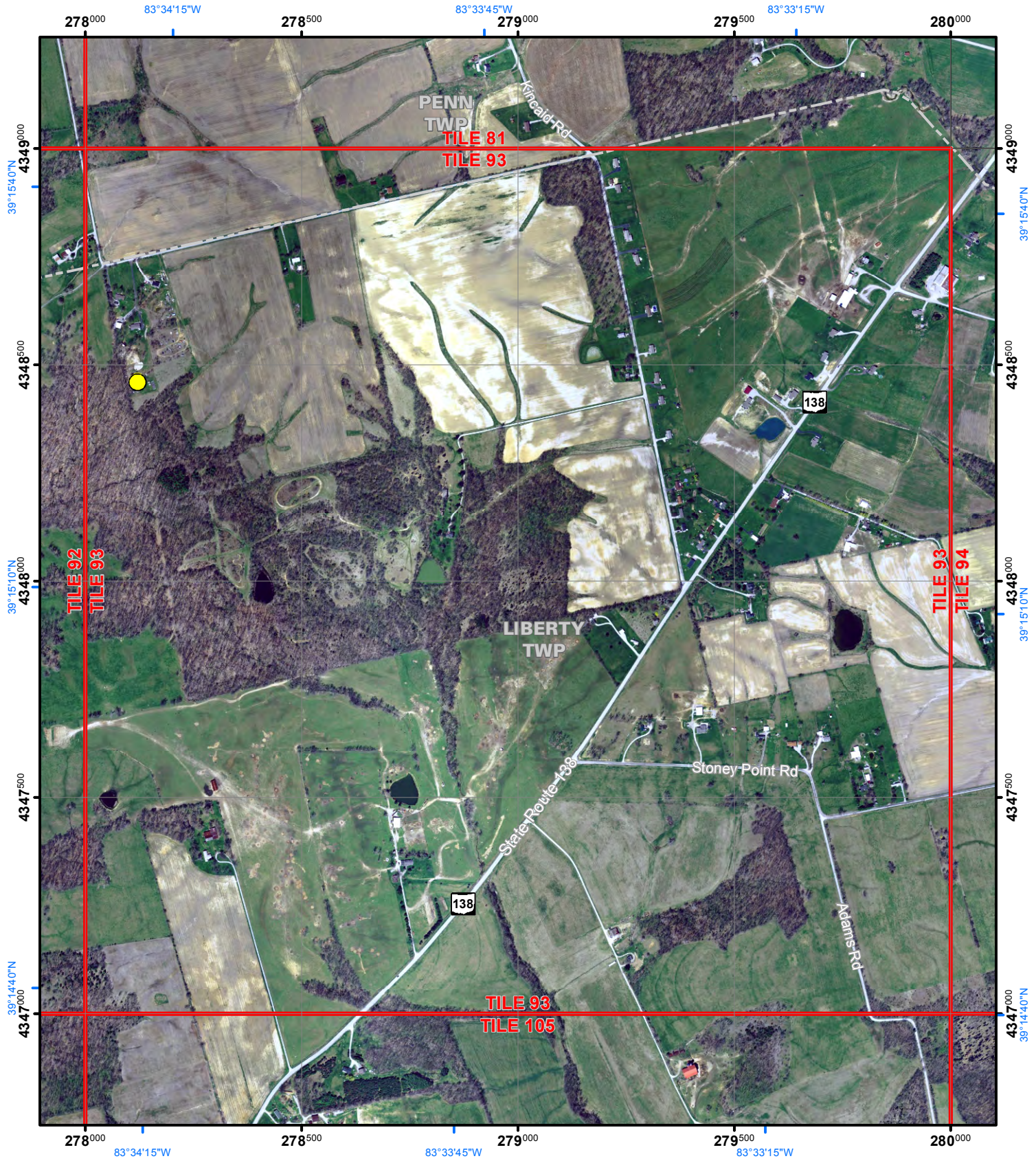
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 93



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

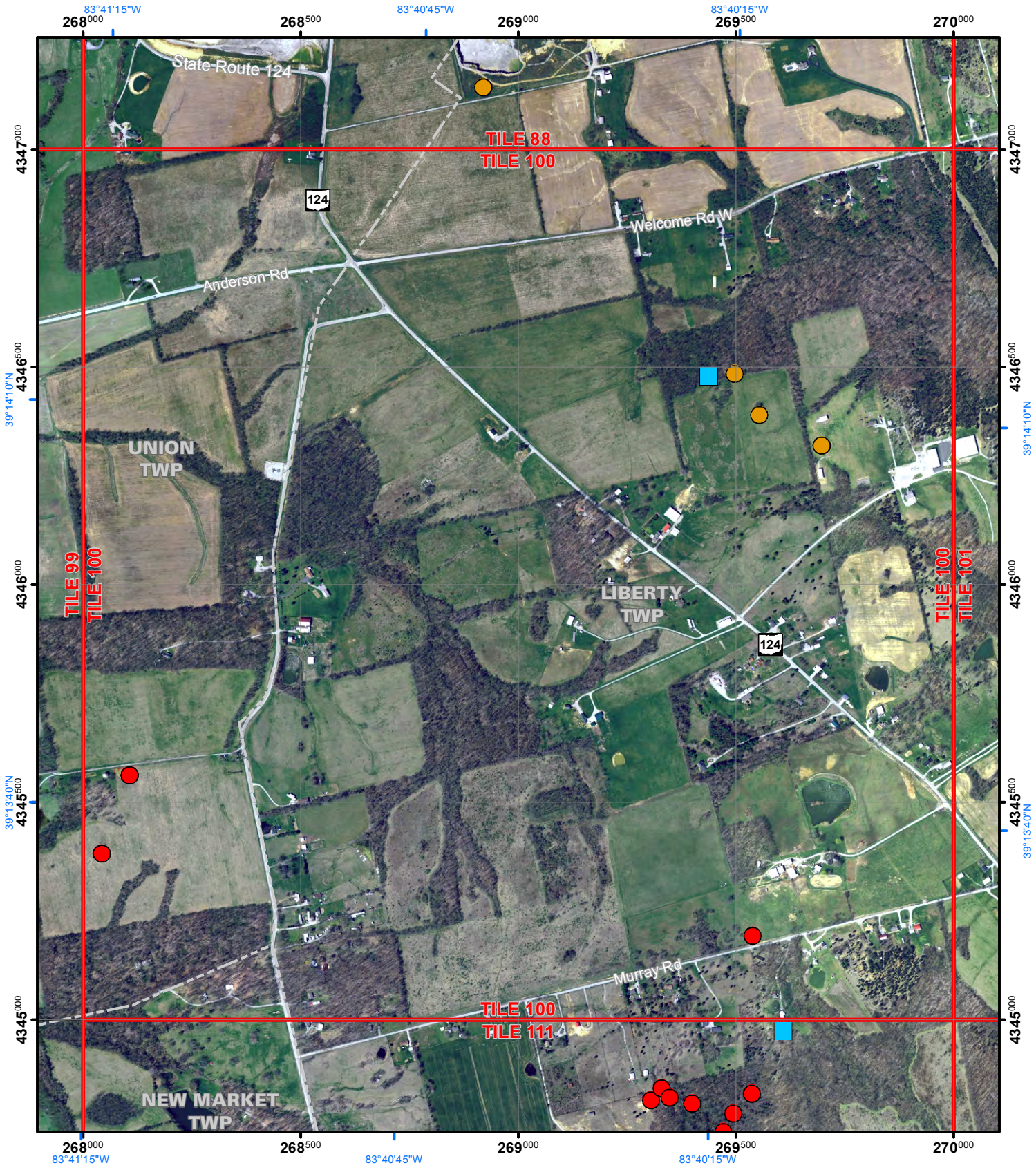
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 100



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

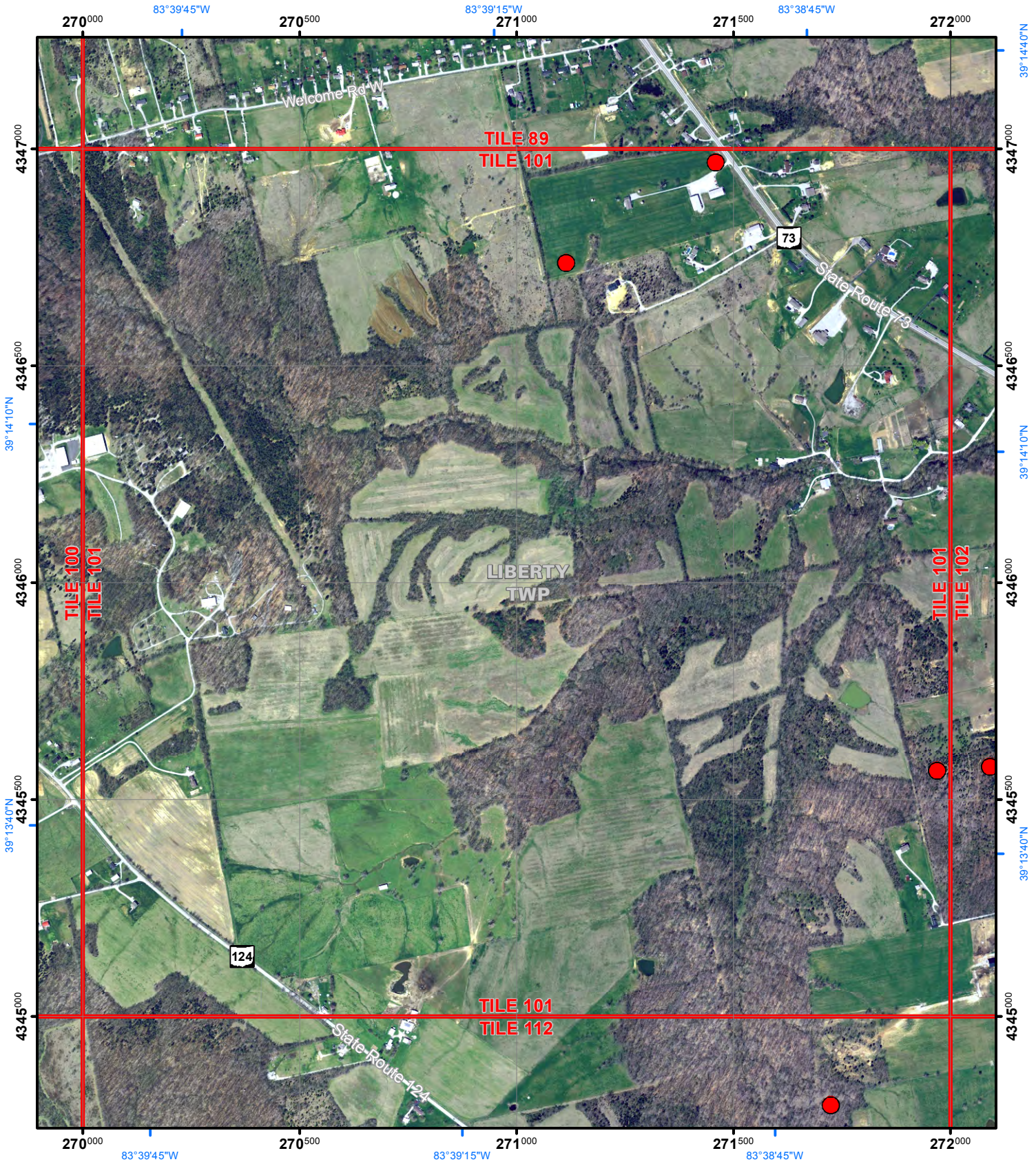
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 101



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

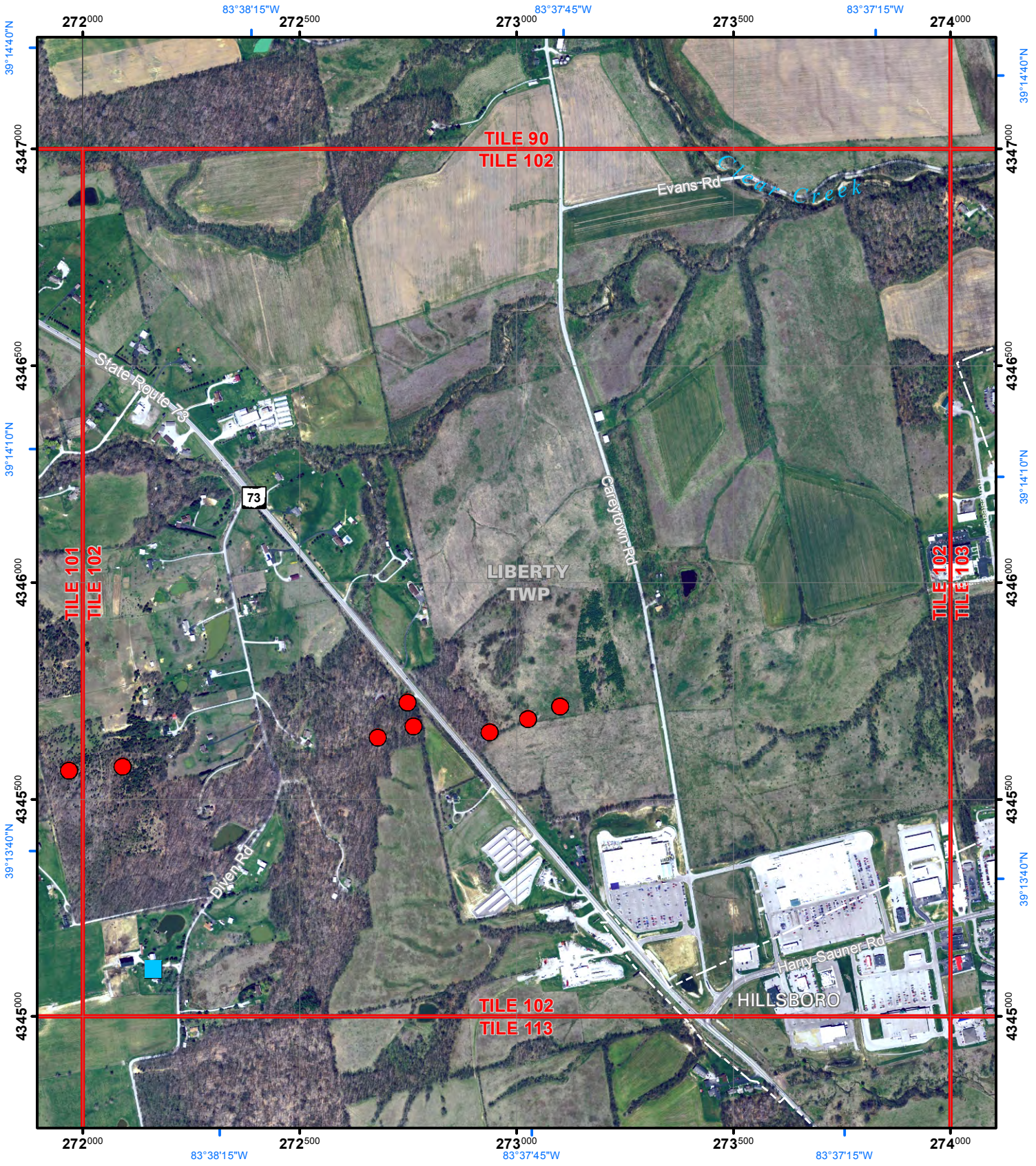
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 102



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

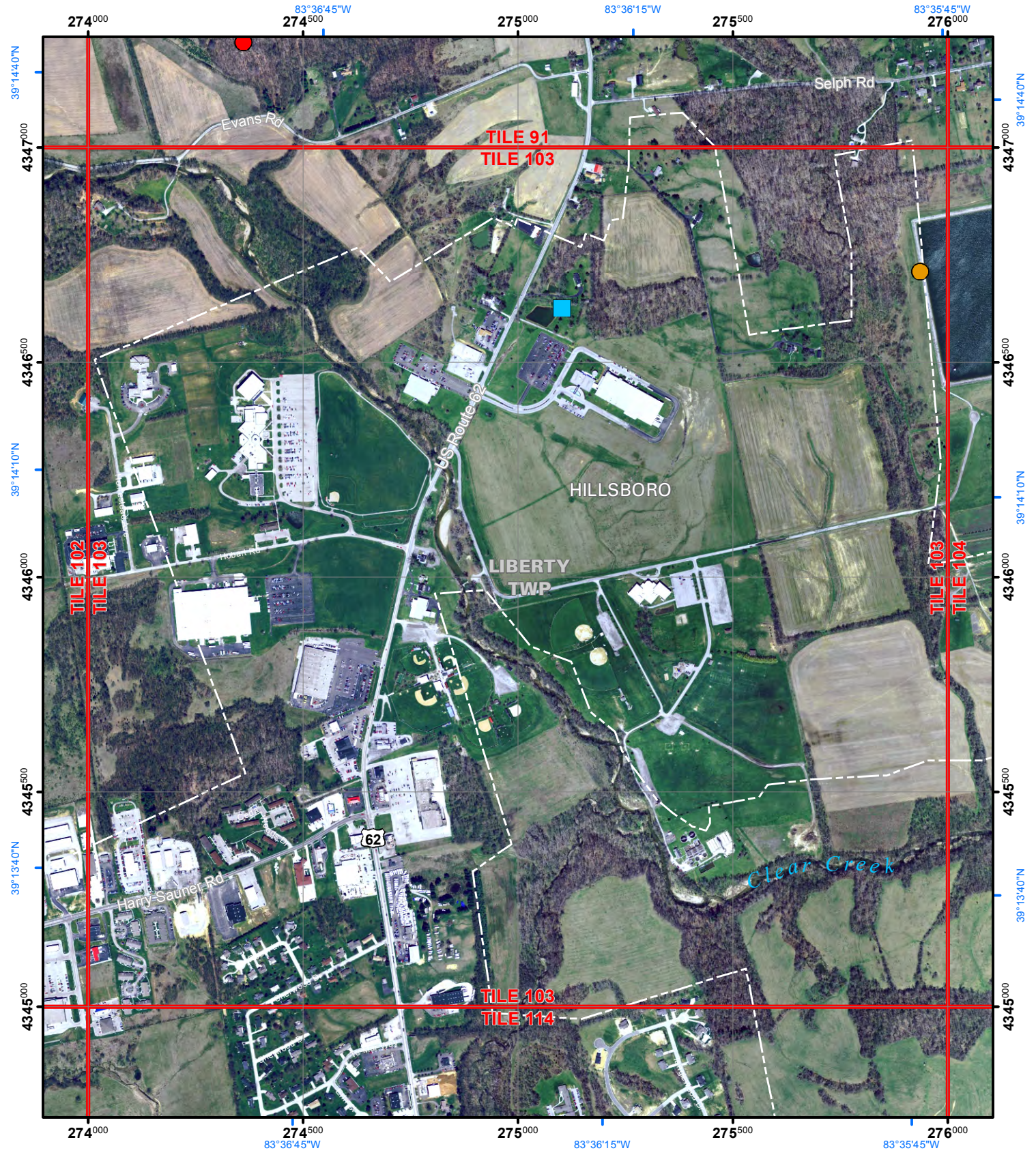
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 103



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 104

US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

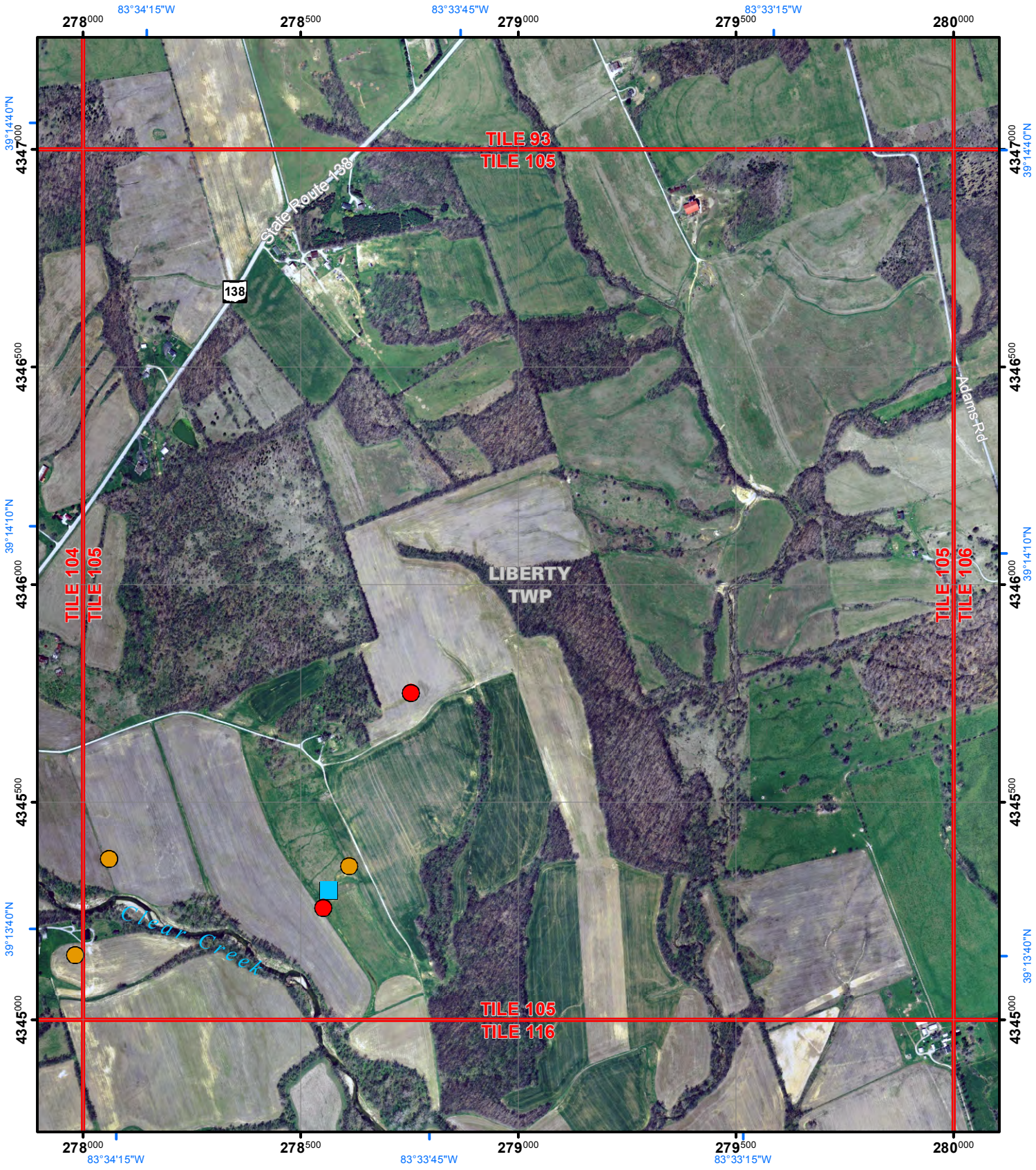
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 105



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

KARST FEATURES

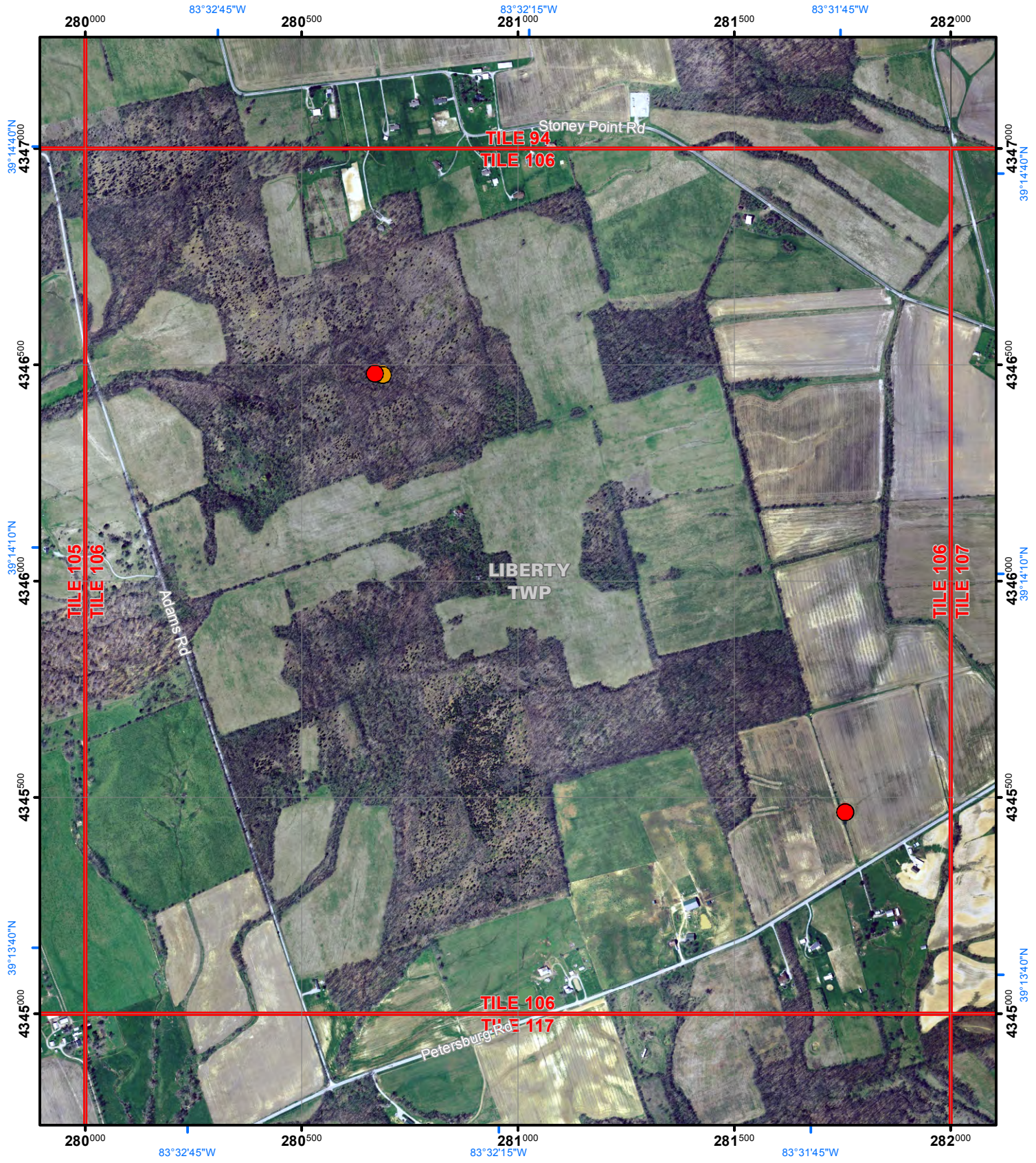
- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION

Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 106



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 107

US National Grid
100,000-m Square ID: KD
Grid Zone Designation: 17S

0 0.5 miles

0 0.5 kilometers

Scale 1:12,000

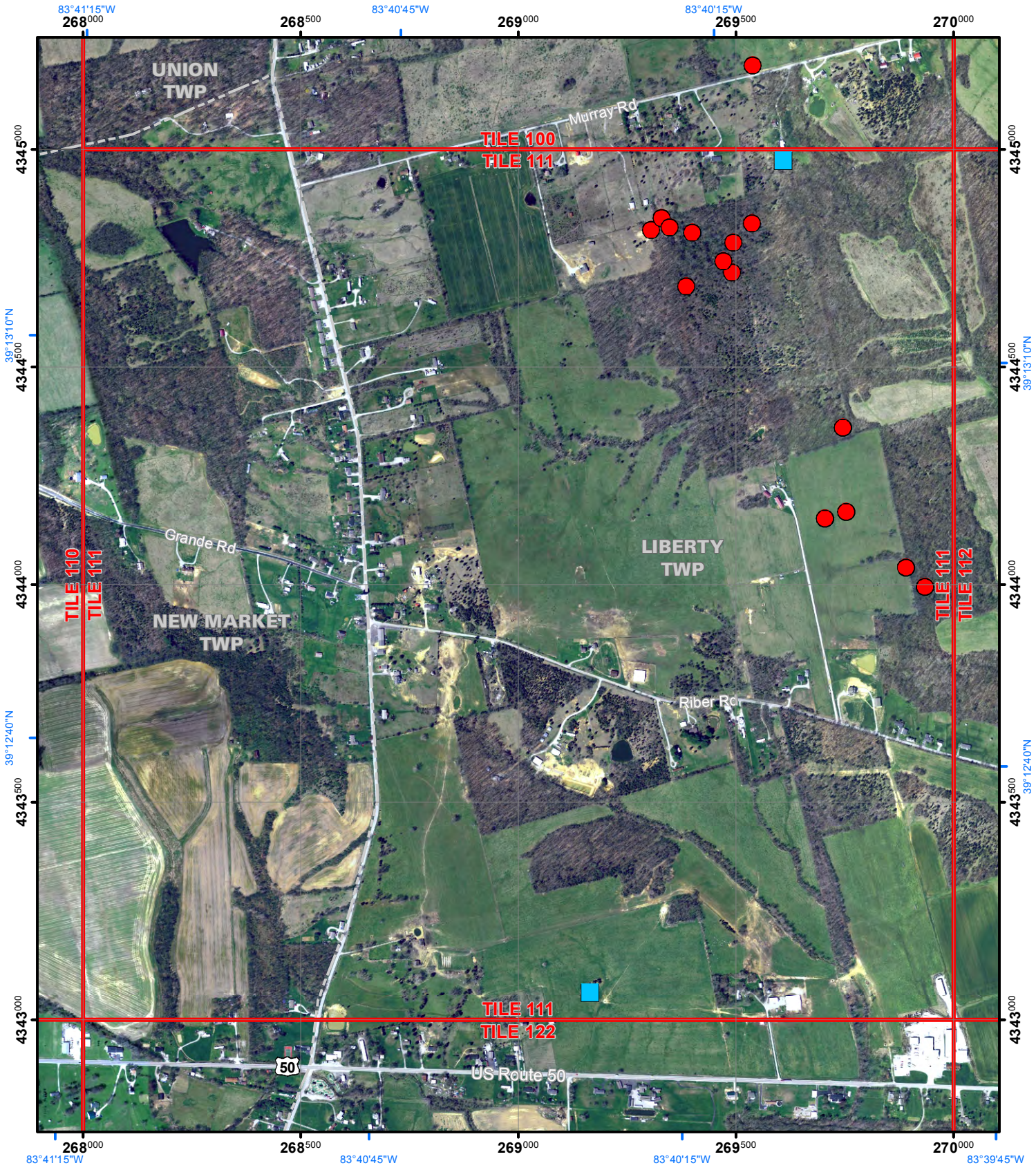
Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

KARST FEATURES
- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 111



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

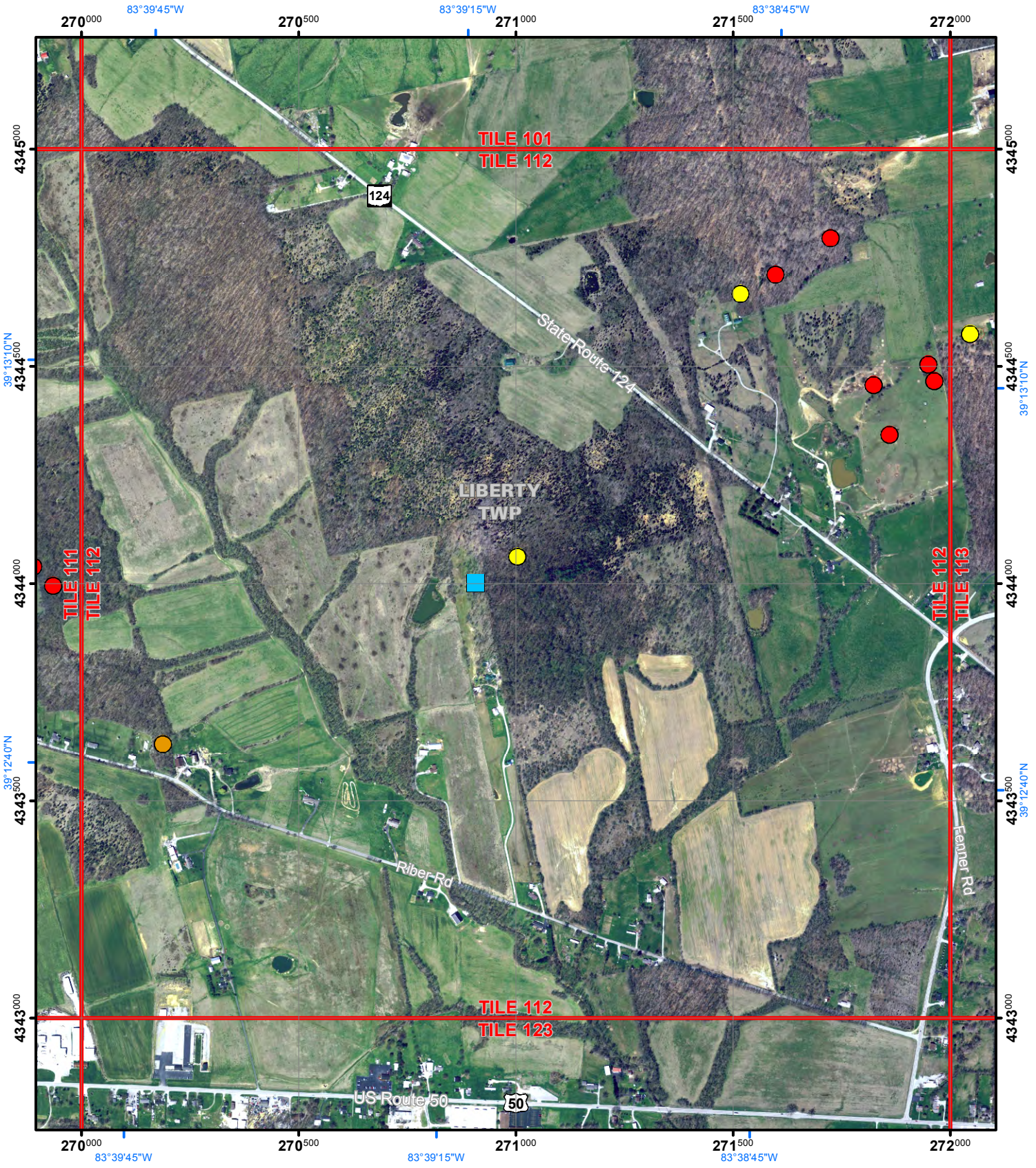
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 112



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

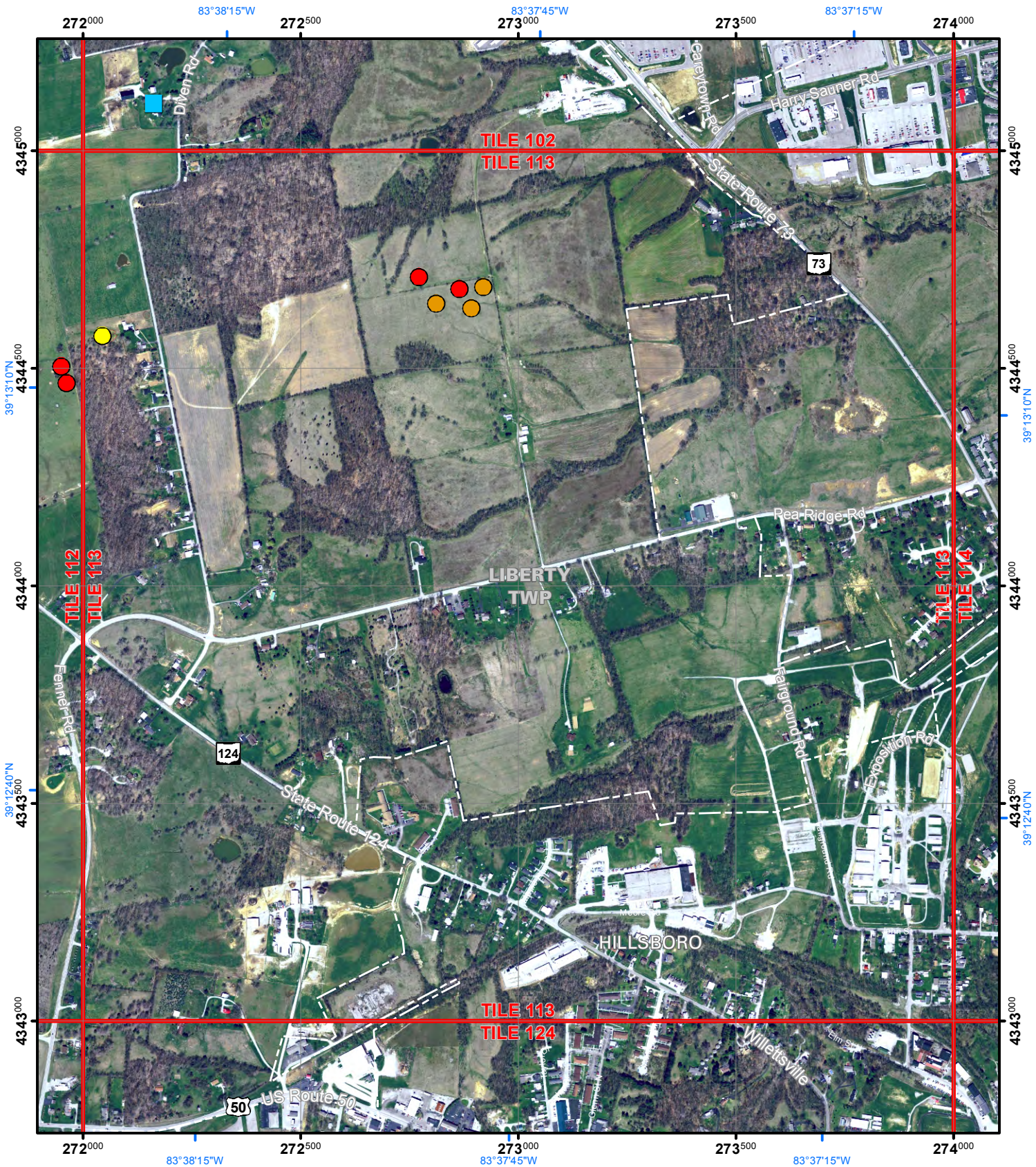
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 113



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 114

US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 115

US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

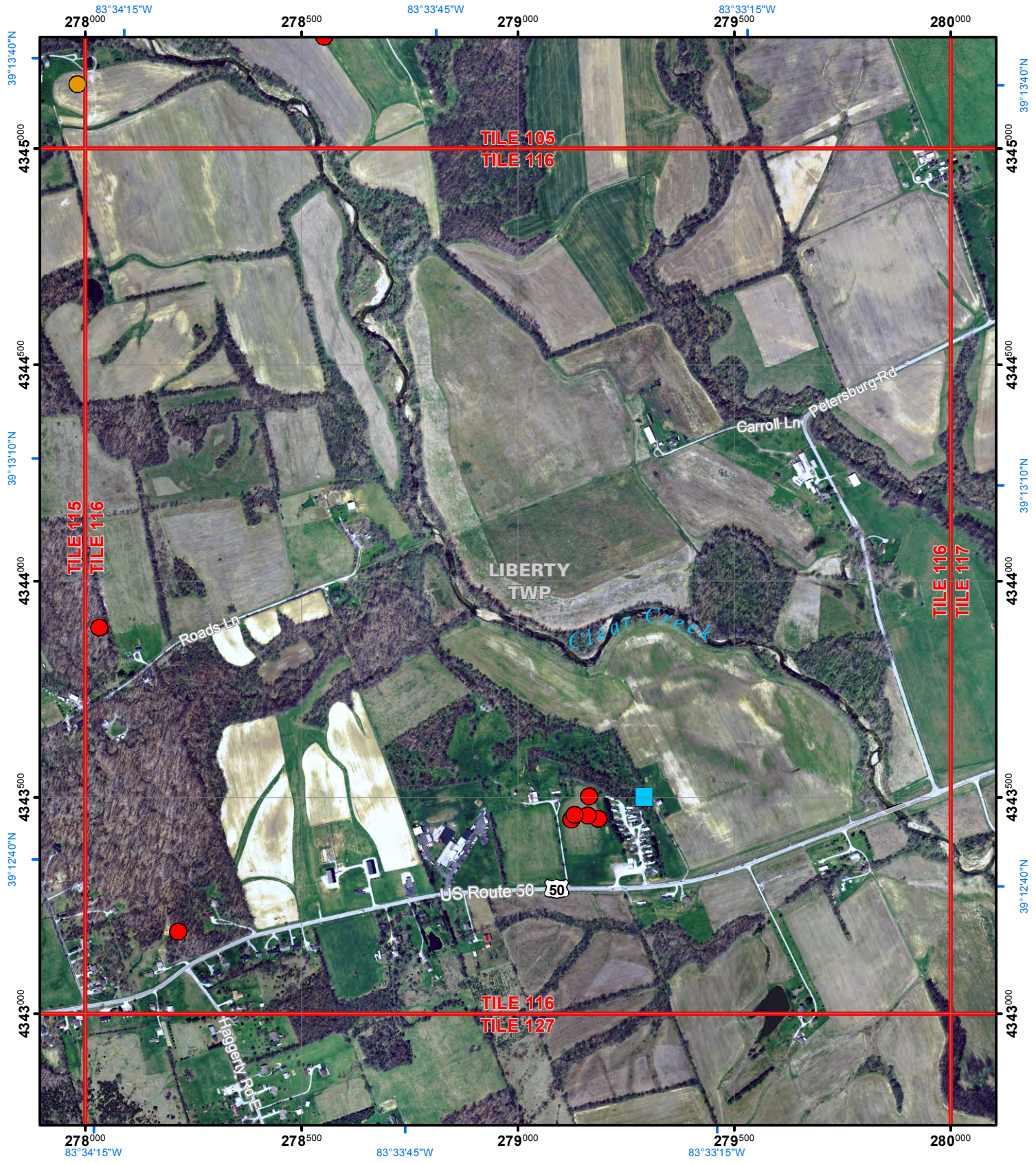
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 116



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

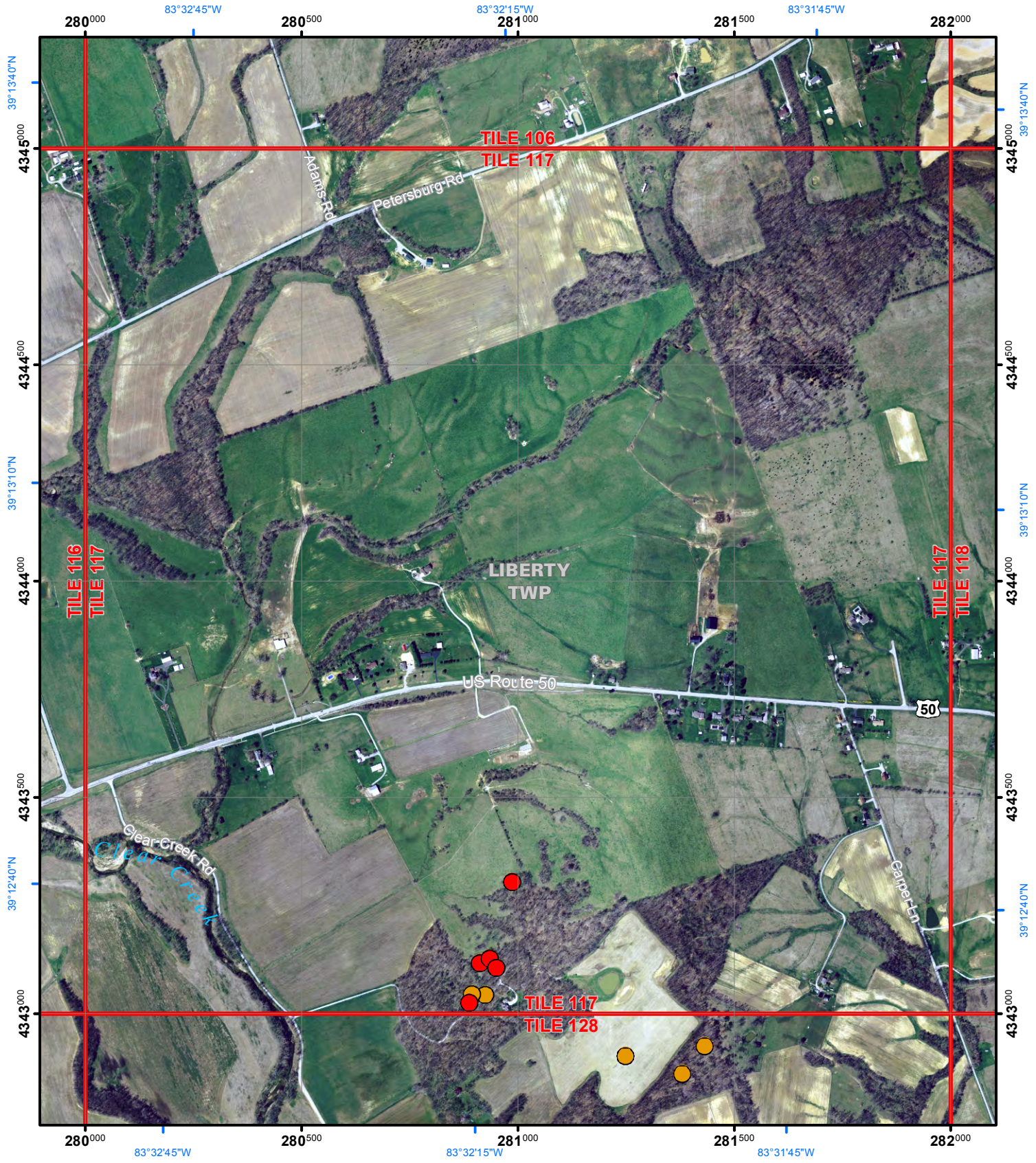
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 117



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 121

US National Grid
100,000-m Square ID: KD
Grid Zone Designation: 17S

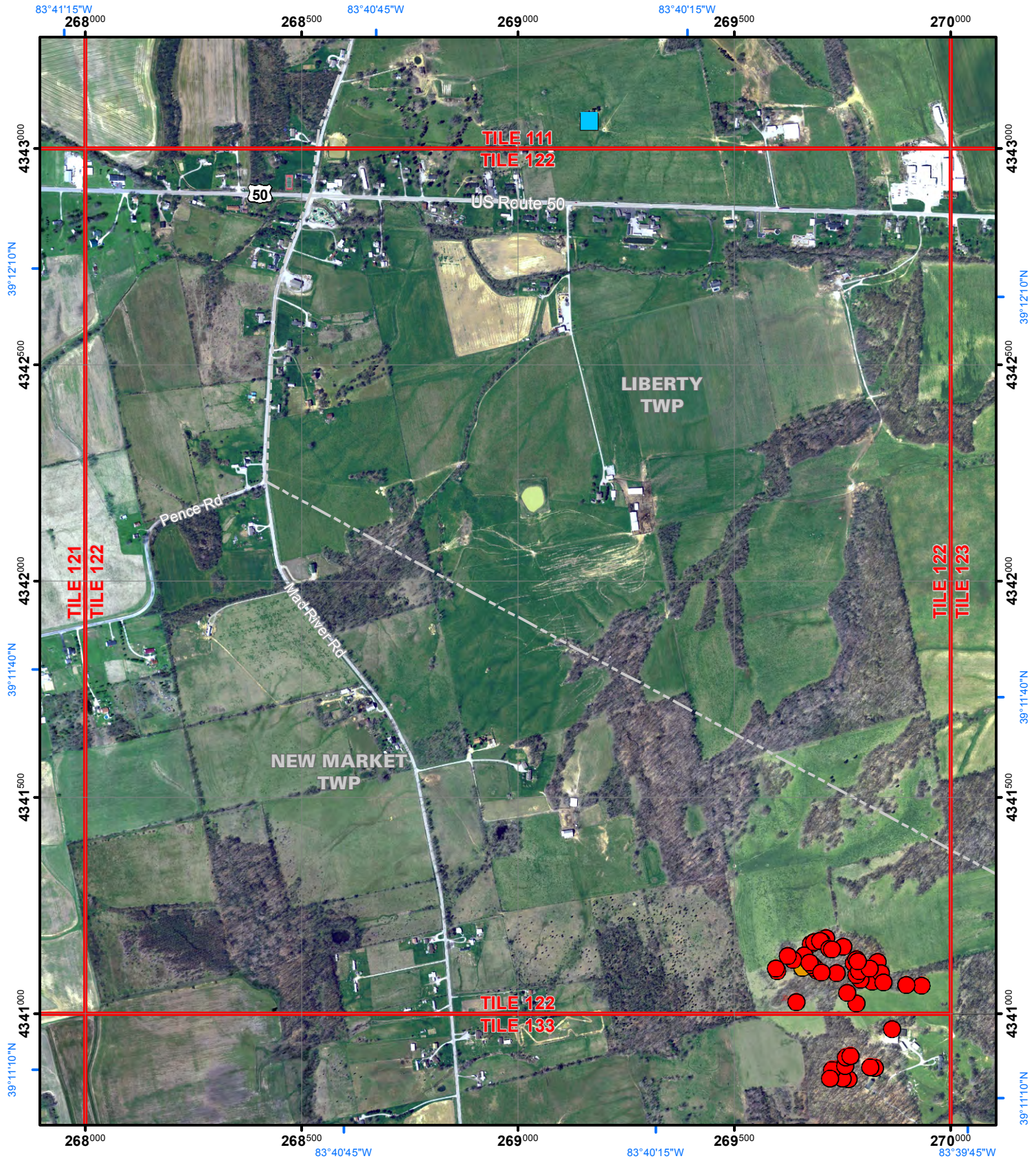
0 0.5 miles
0 0.5 kilometers
Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

KARST FEATURES
- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet
1 2 3 4 5 6 7 8 9 10

Tile Number: 122



US National Grid

100,000-m Square ID: KD

Grid Zone Designation: 17S

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

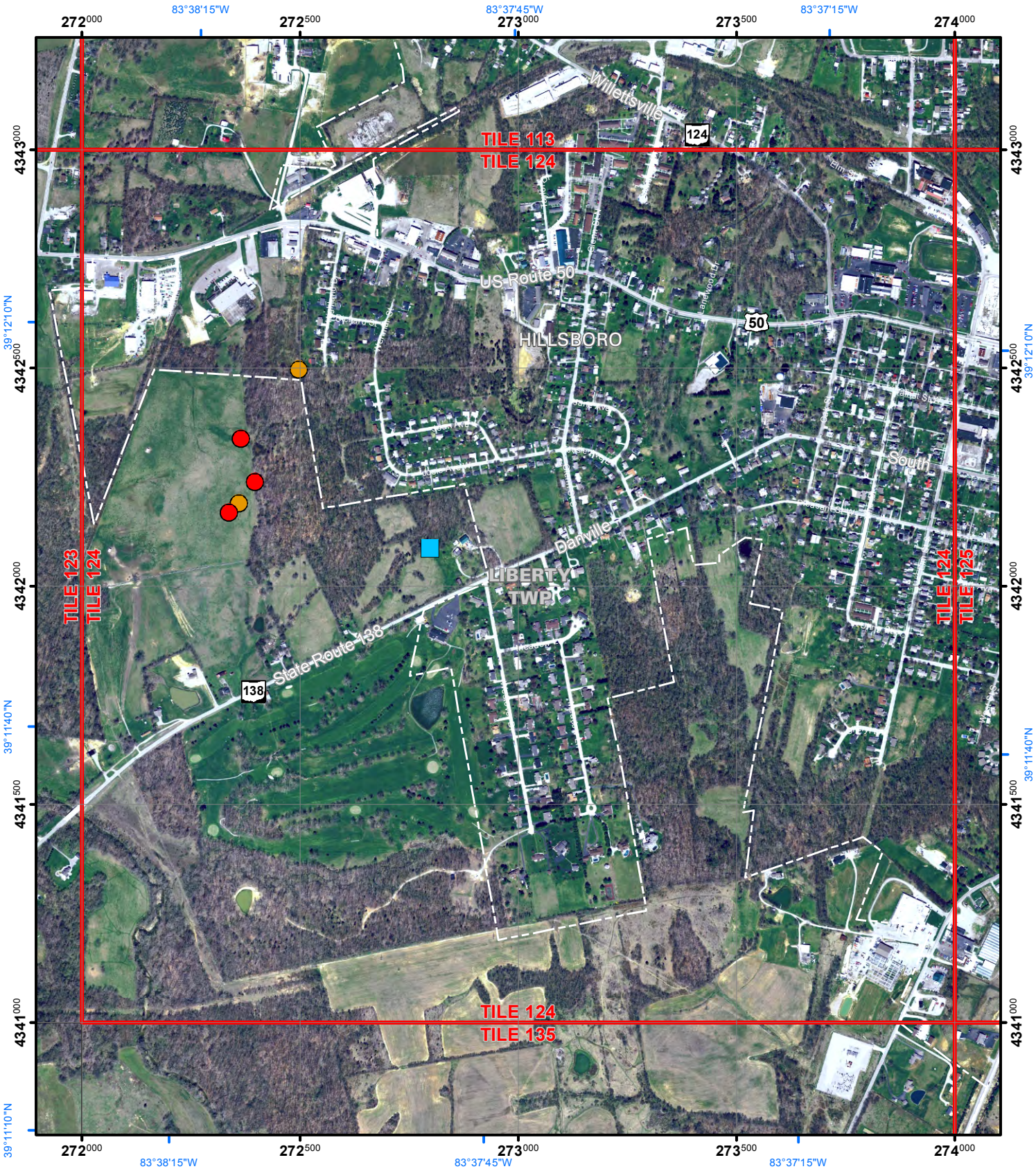
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 124



US National Grid

100,000-m Square ID: KD

Grid Zone Designation: 17S

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

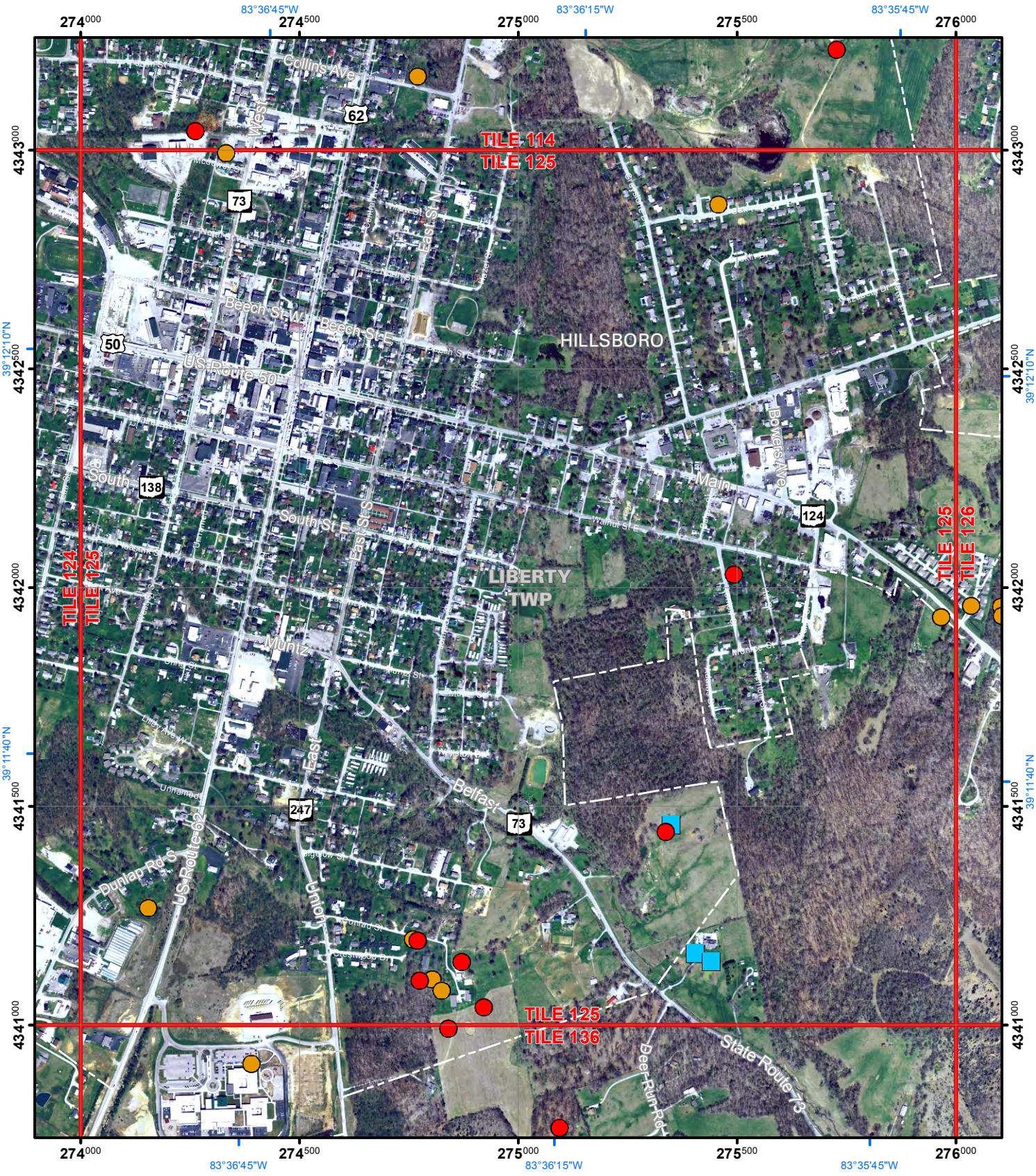
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 125



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

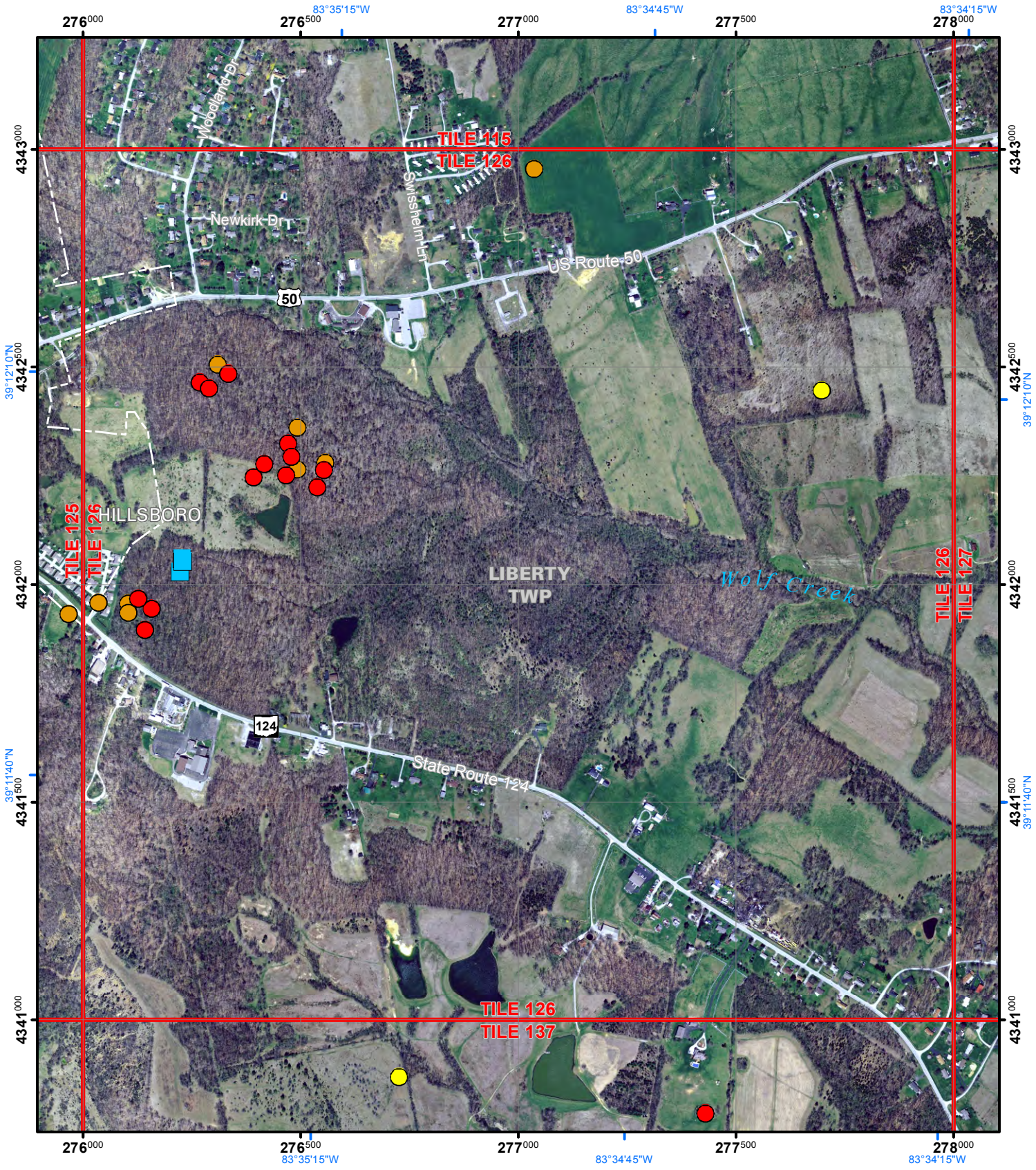
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 126



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

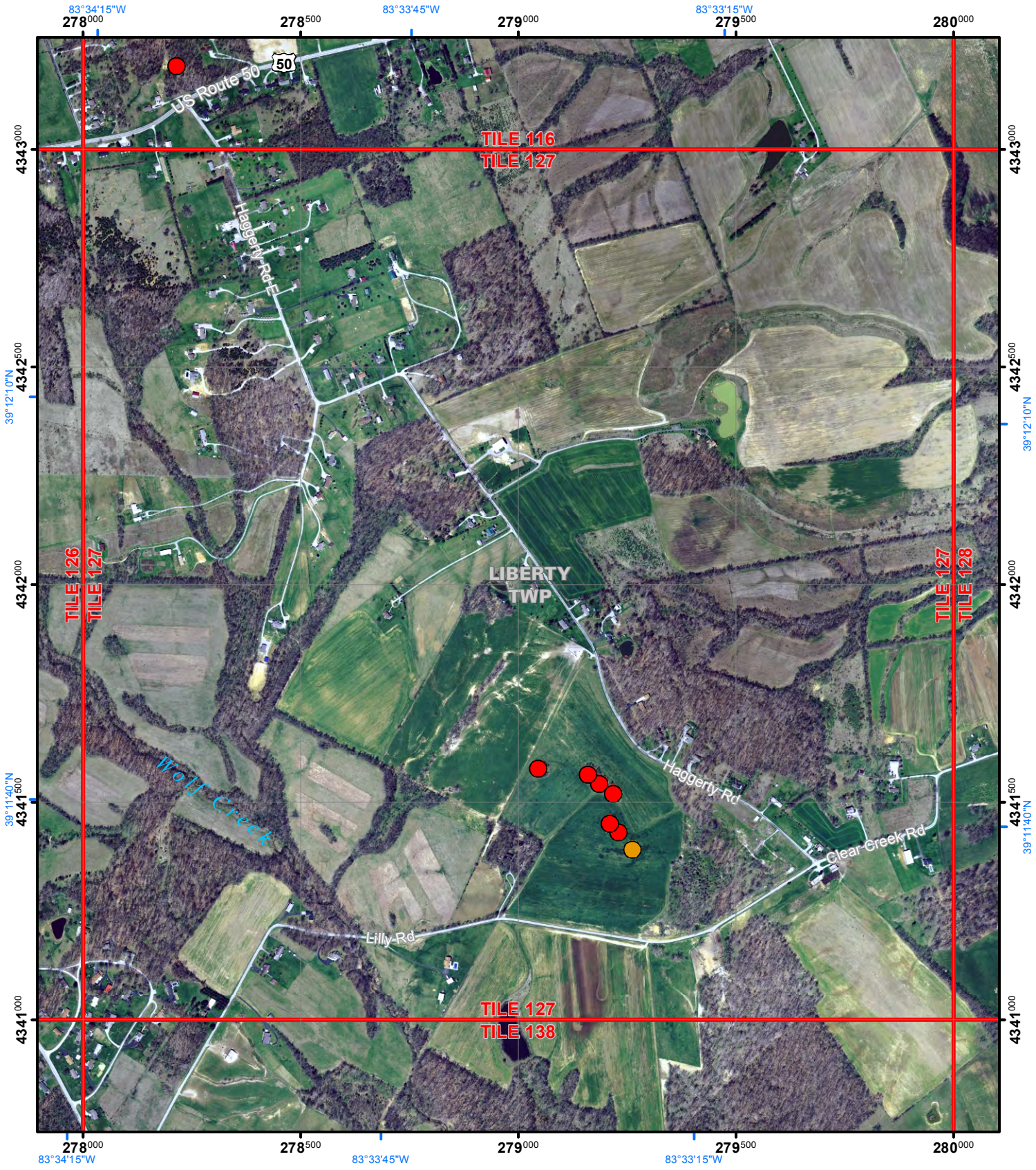
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 127



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 128

US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 129

US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

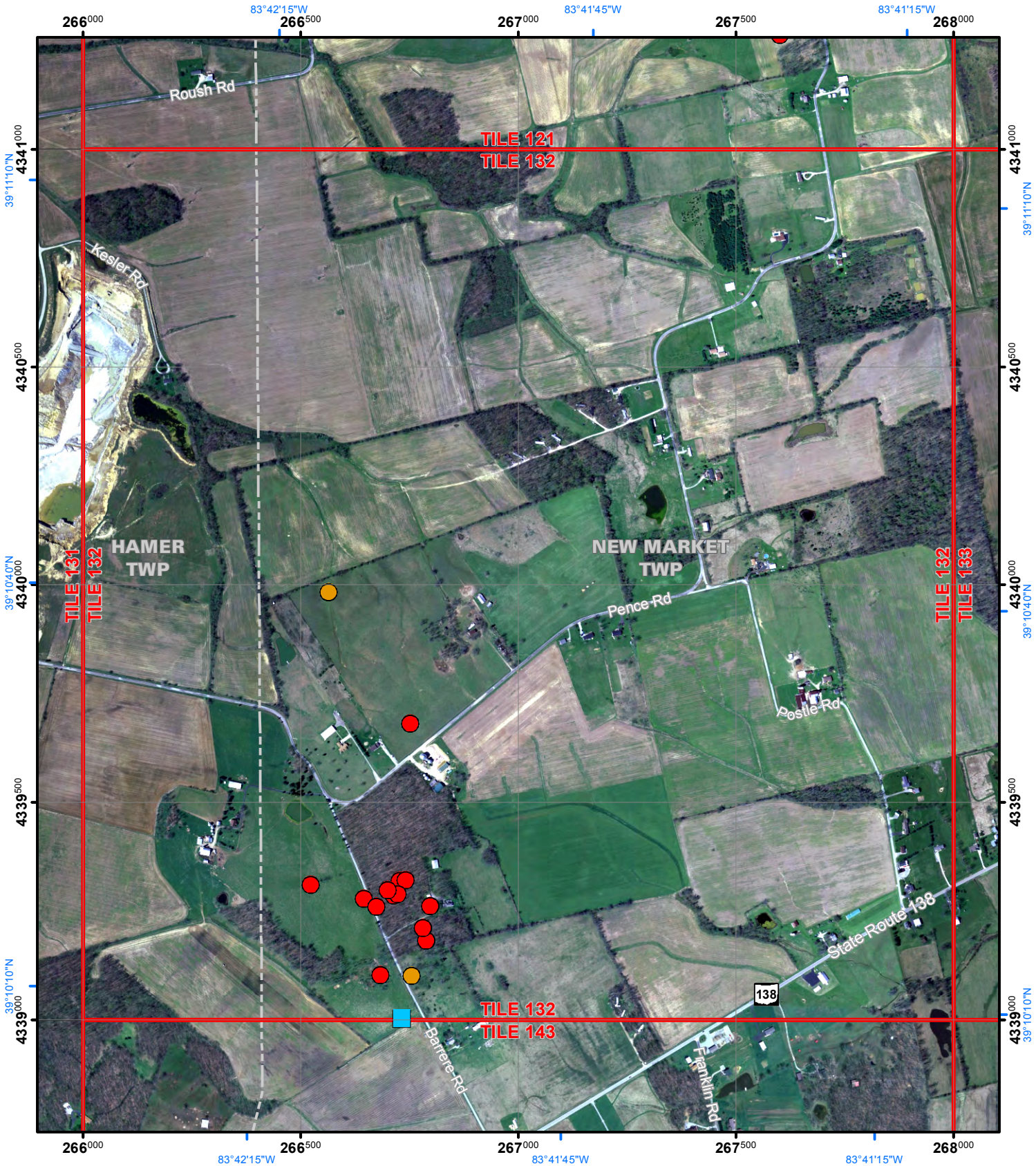
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 132



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

N W E S

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

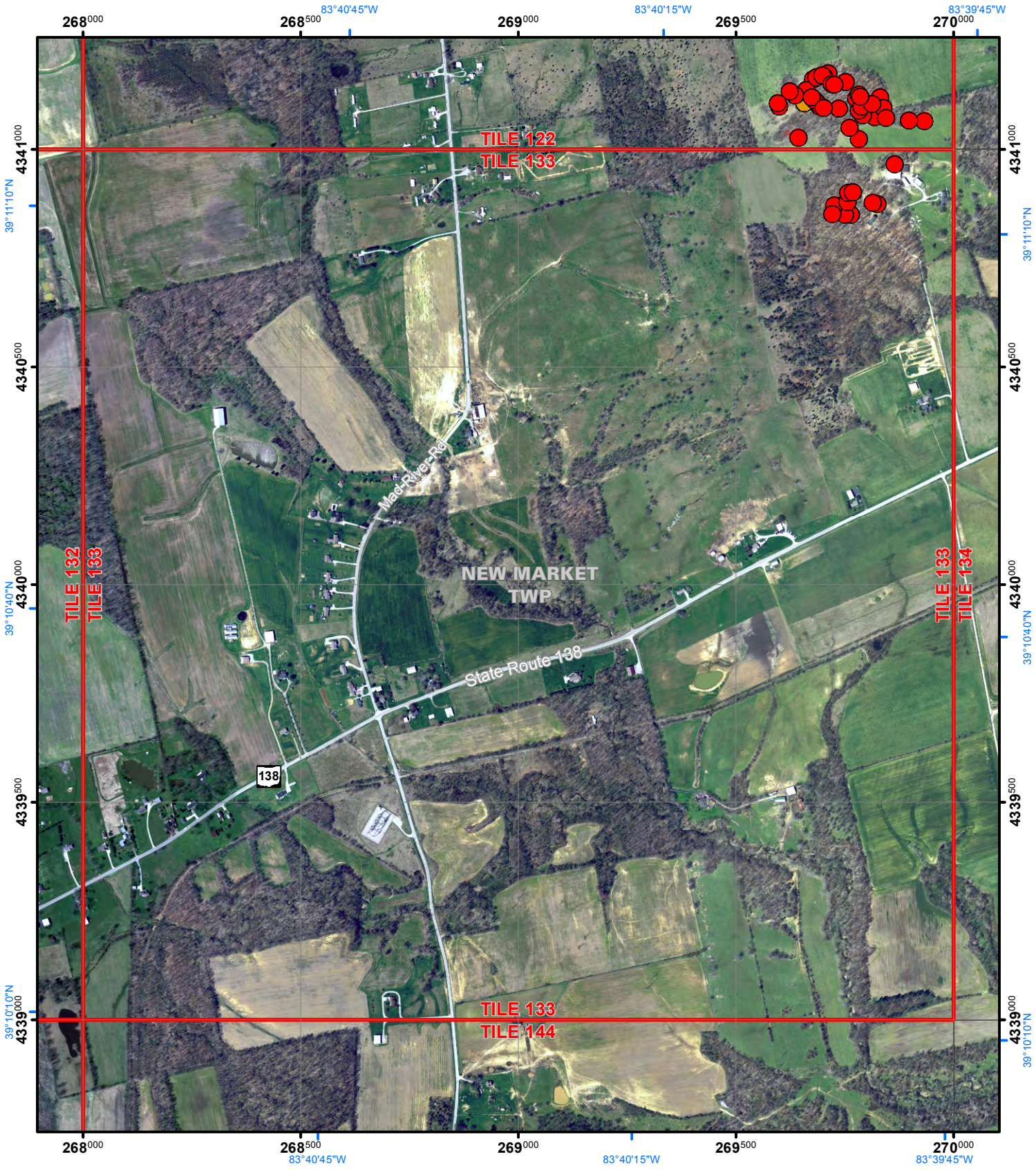
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 133



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 136

US National Grid
100,000-m Square ID: KD
Grid Zone Designation: 17S

0 0.5 miles

0 0.5 kilometers

Scale 1:12,000

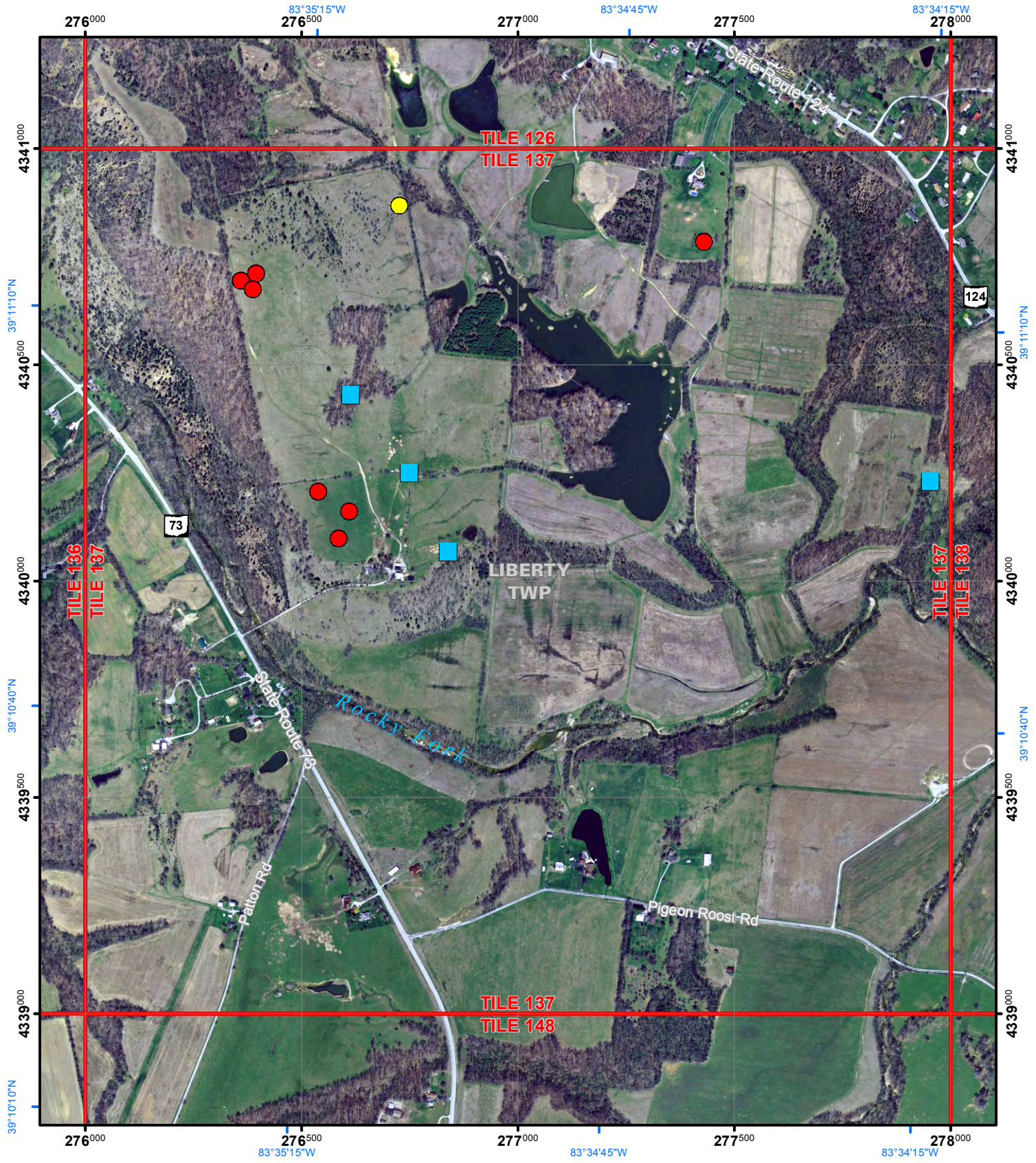
Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

KARST FEATURES
- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 137



US National Grid

100,000-m Square ID: KD

Grid Zone Designation: 17S

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

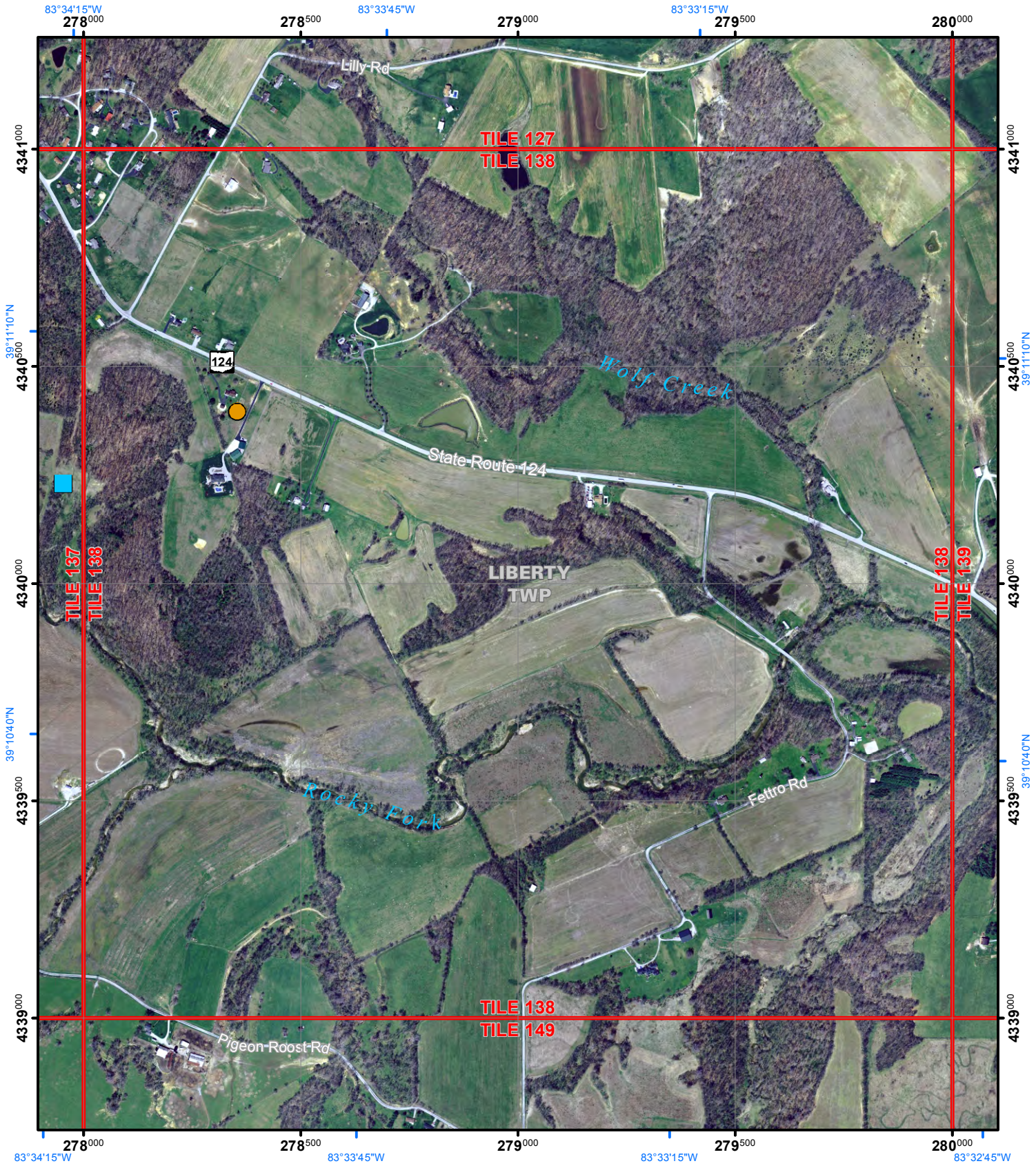
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 138



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

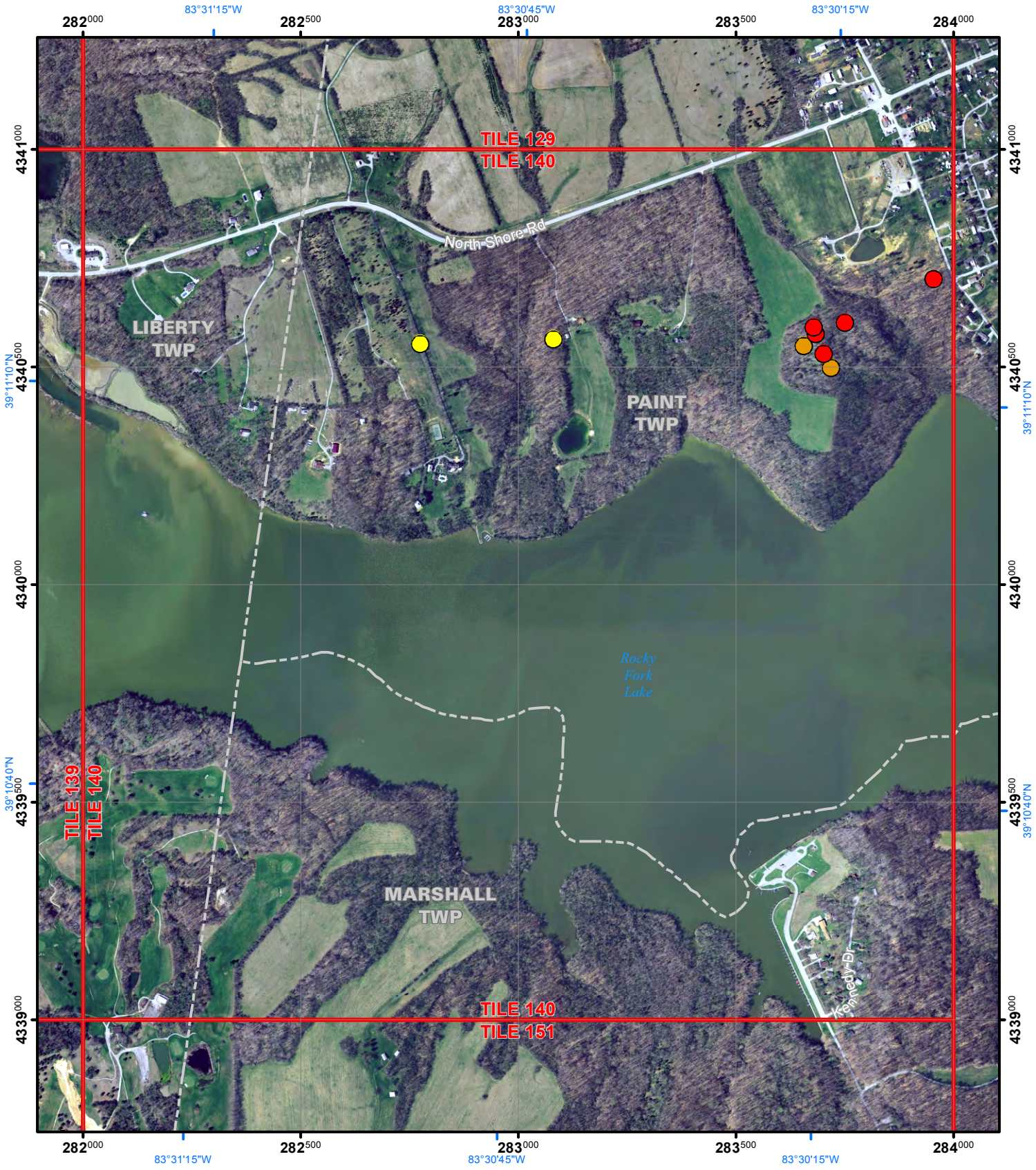
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 140



US National Grid
100,000-m Square ID: KD
Grid Zone Designation: 17S

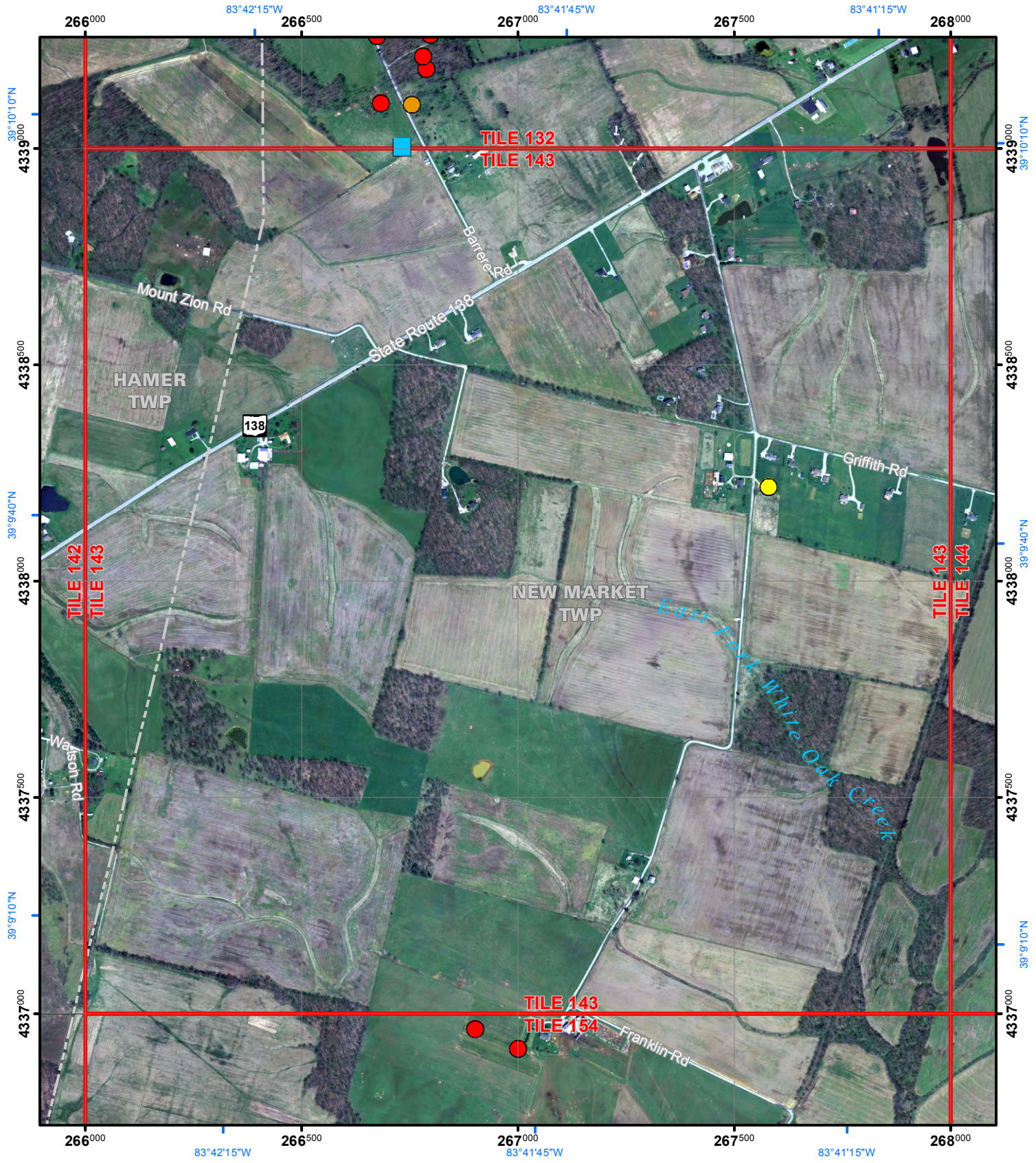
0 — 0.5 miles
0 — 0.5 kilometers
Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

KARST FEATURES
- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet
1 2 3 4 5 6 7 8 9 10

Tile Number: 143



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

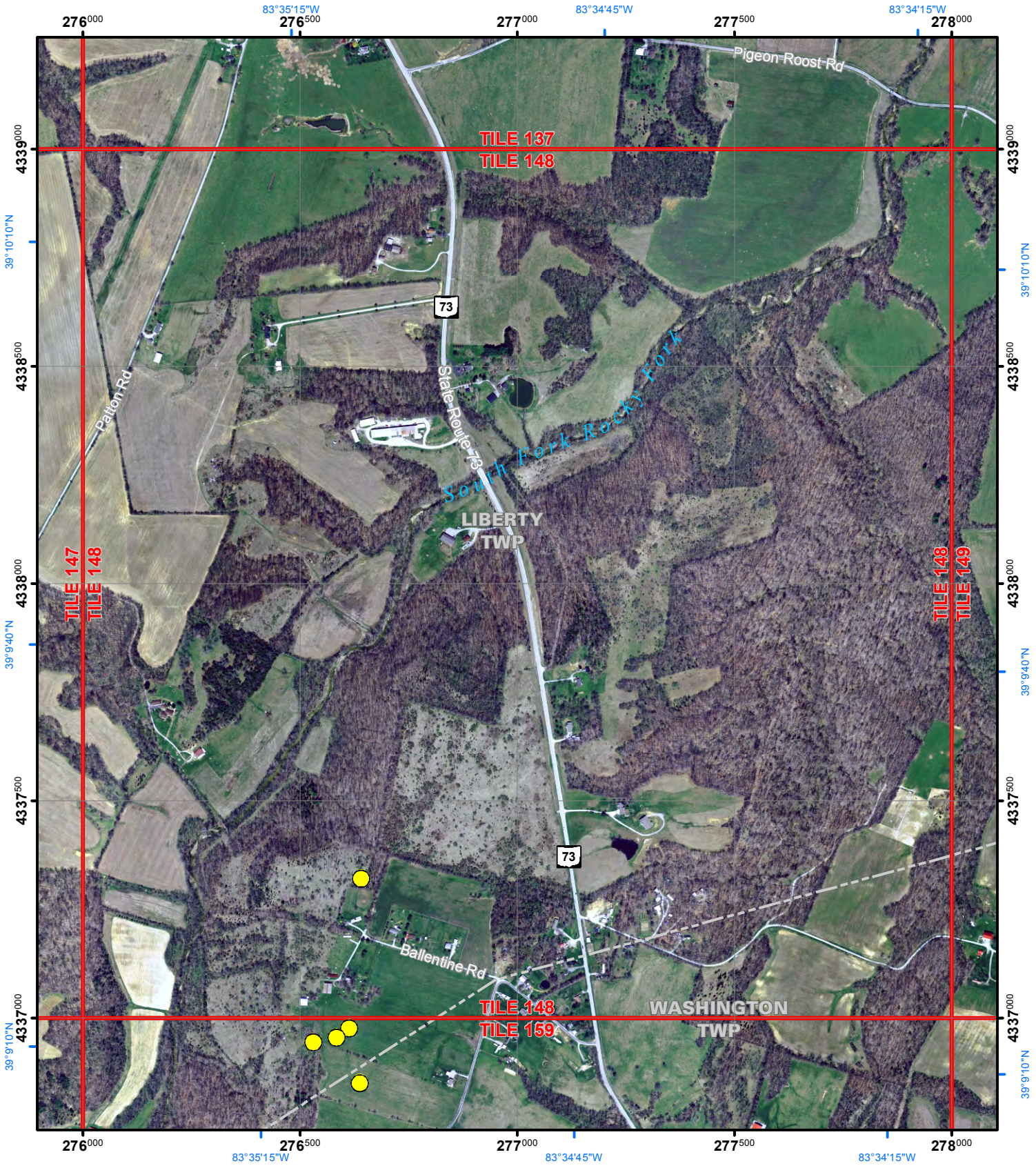
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 148



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

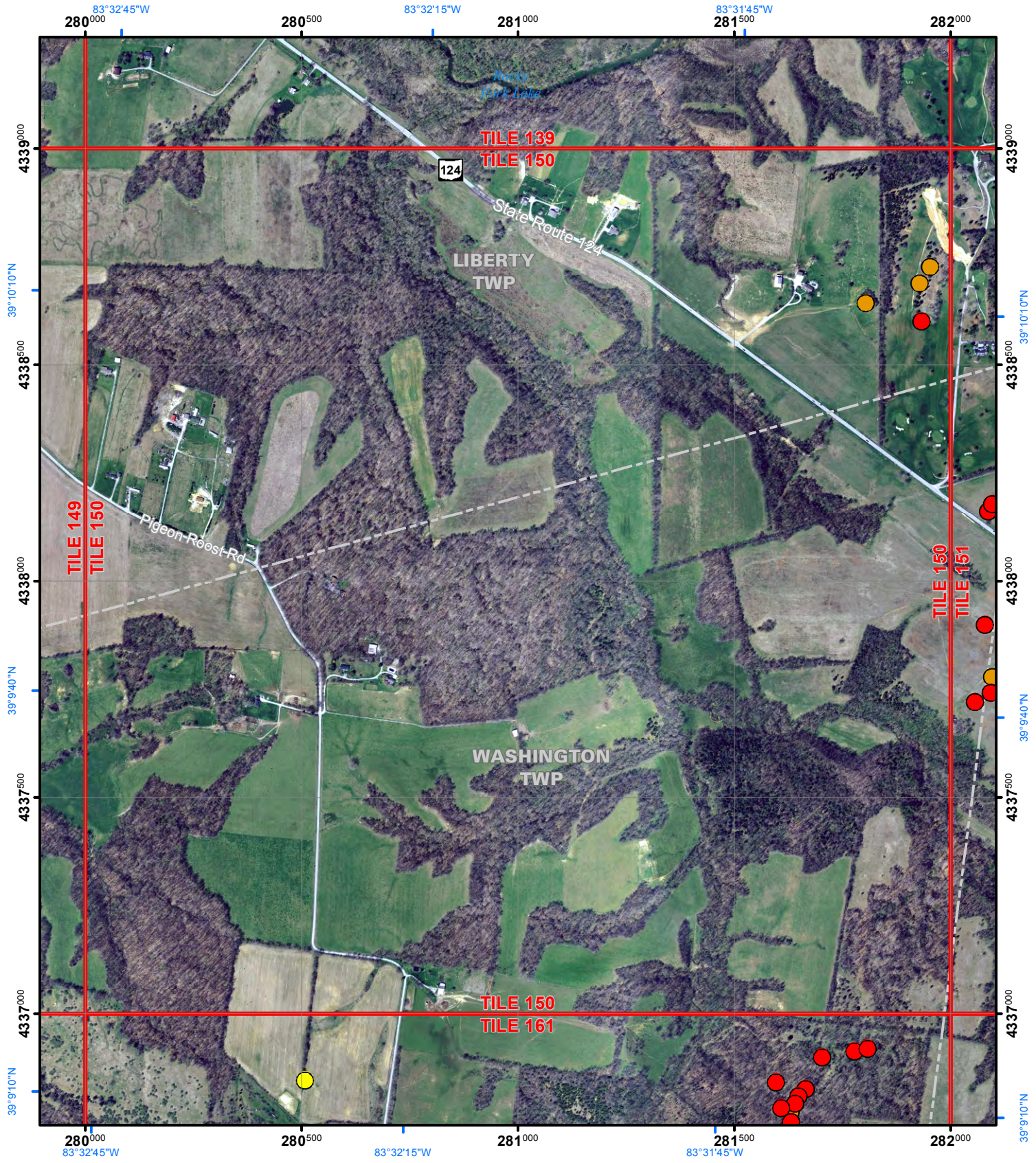
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 150



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

N W E S

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

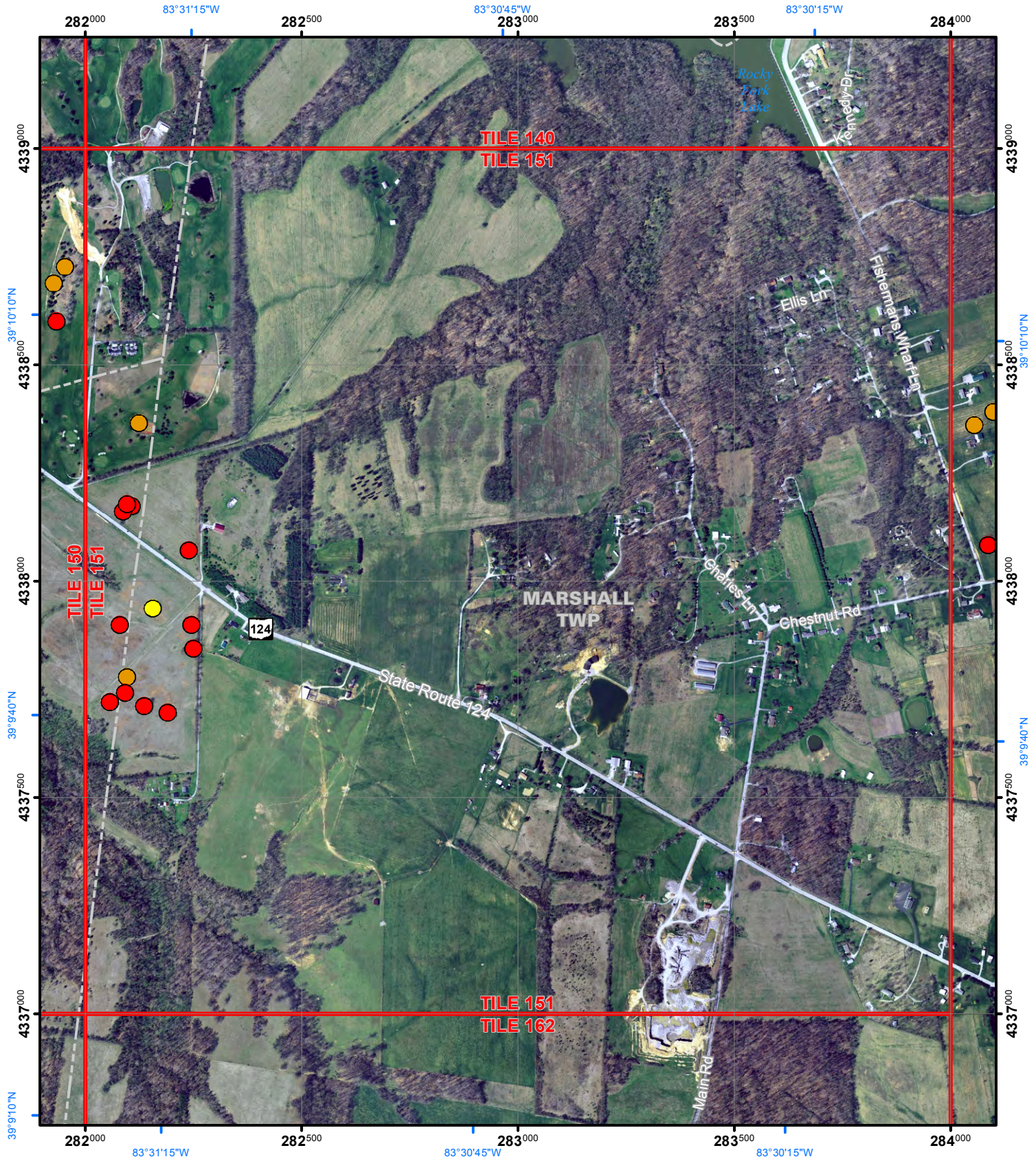
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 151



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 154

US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 155

US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

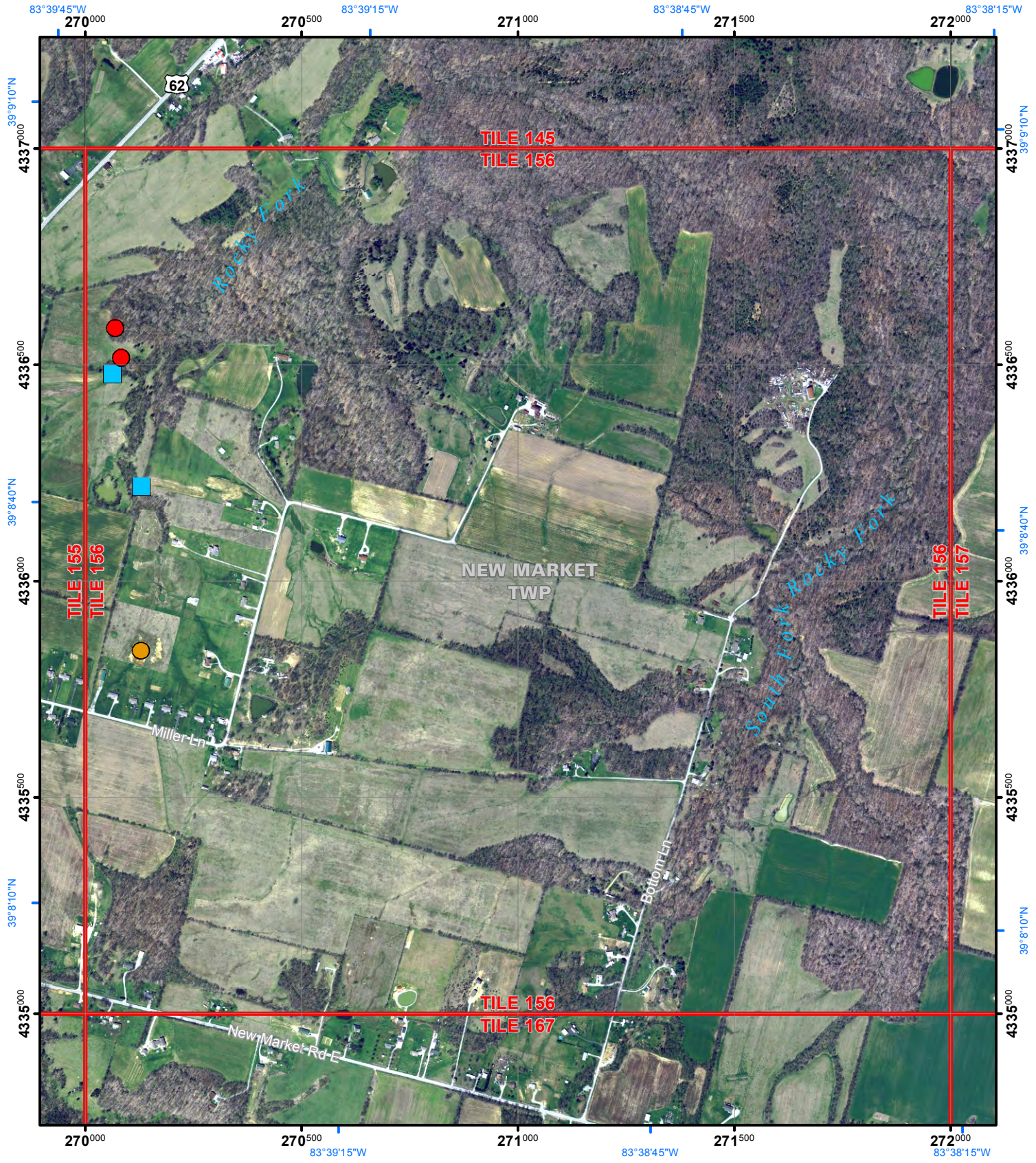
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 156



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 157

US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

N W E S

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

Tile Number: 158

US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

N W E S

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

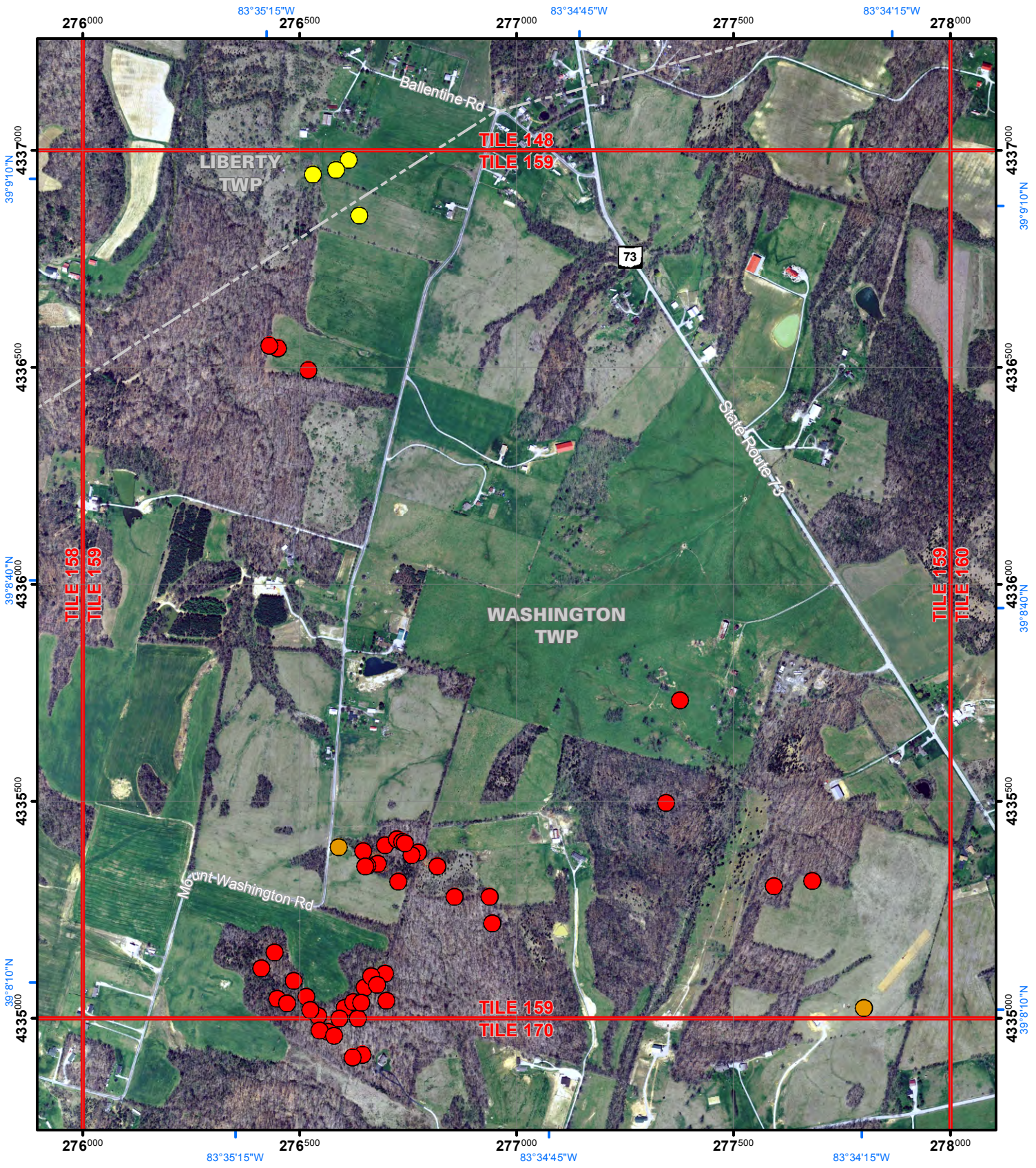
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 159



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

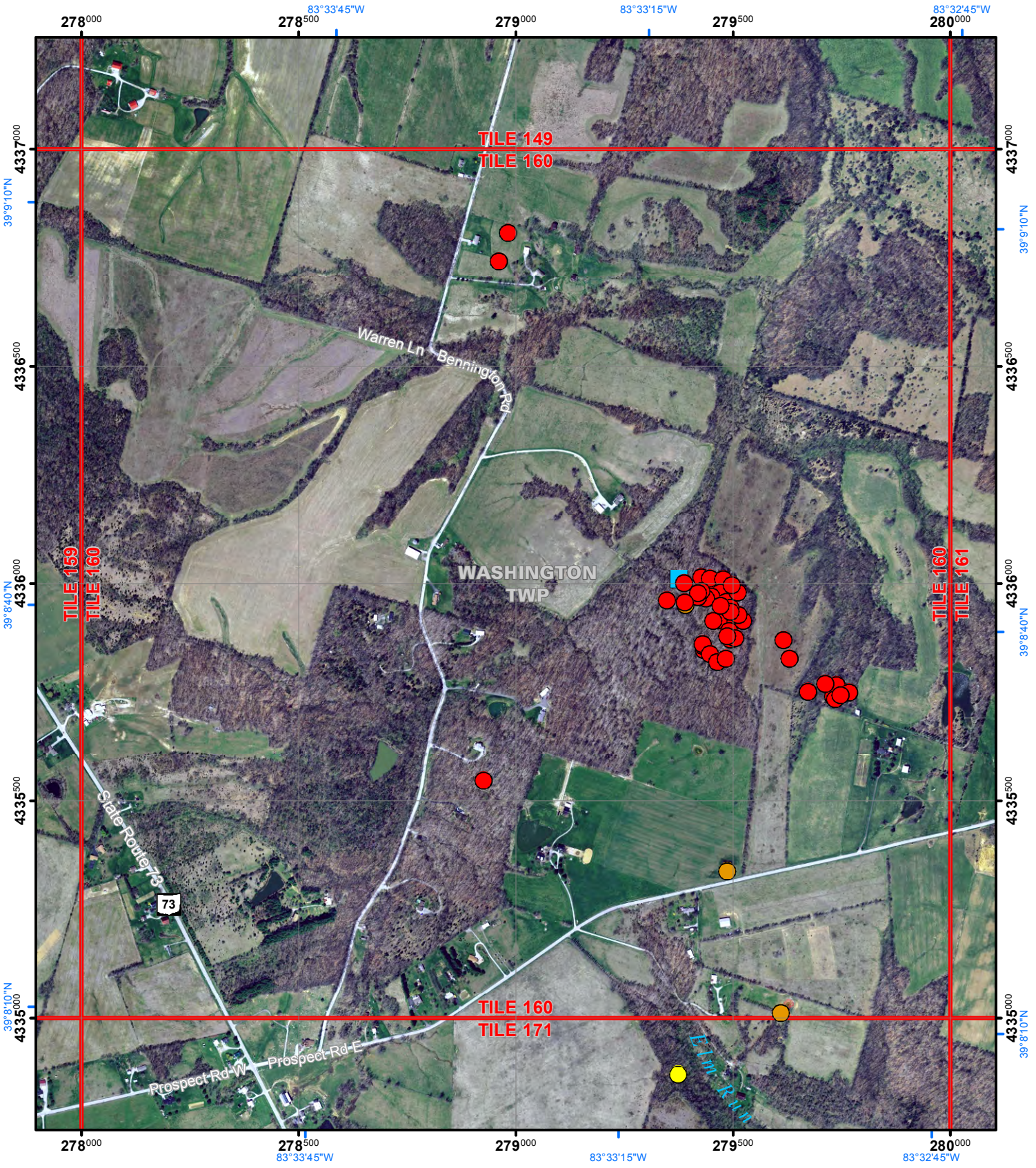
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 160



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

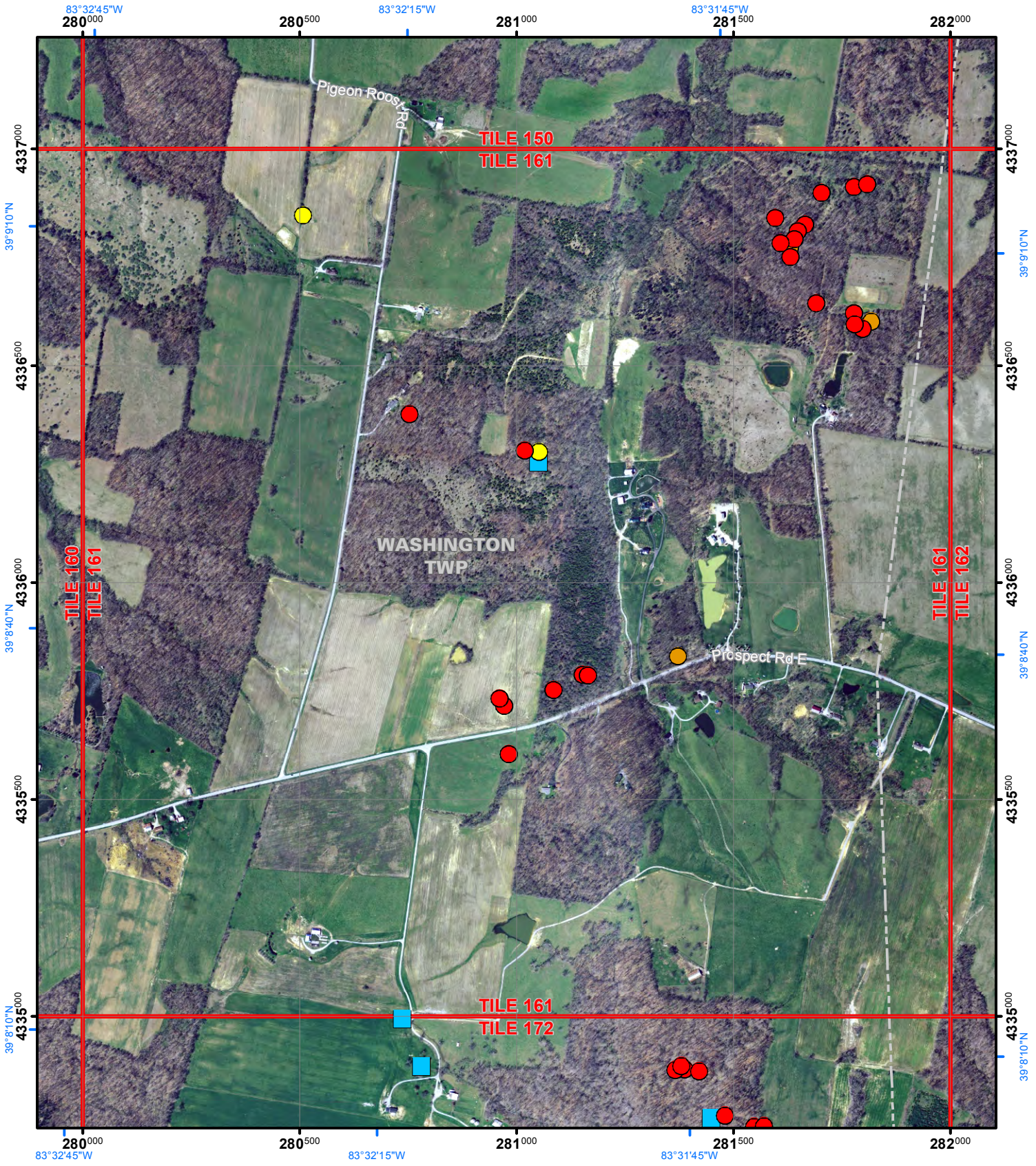
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 161



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

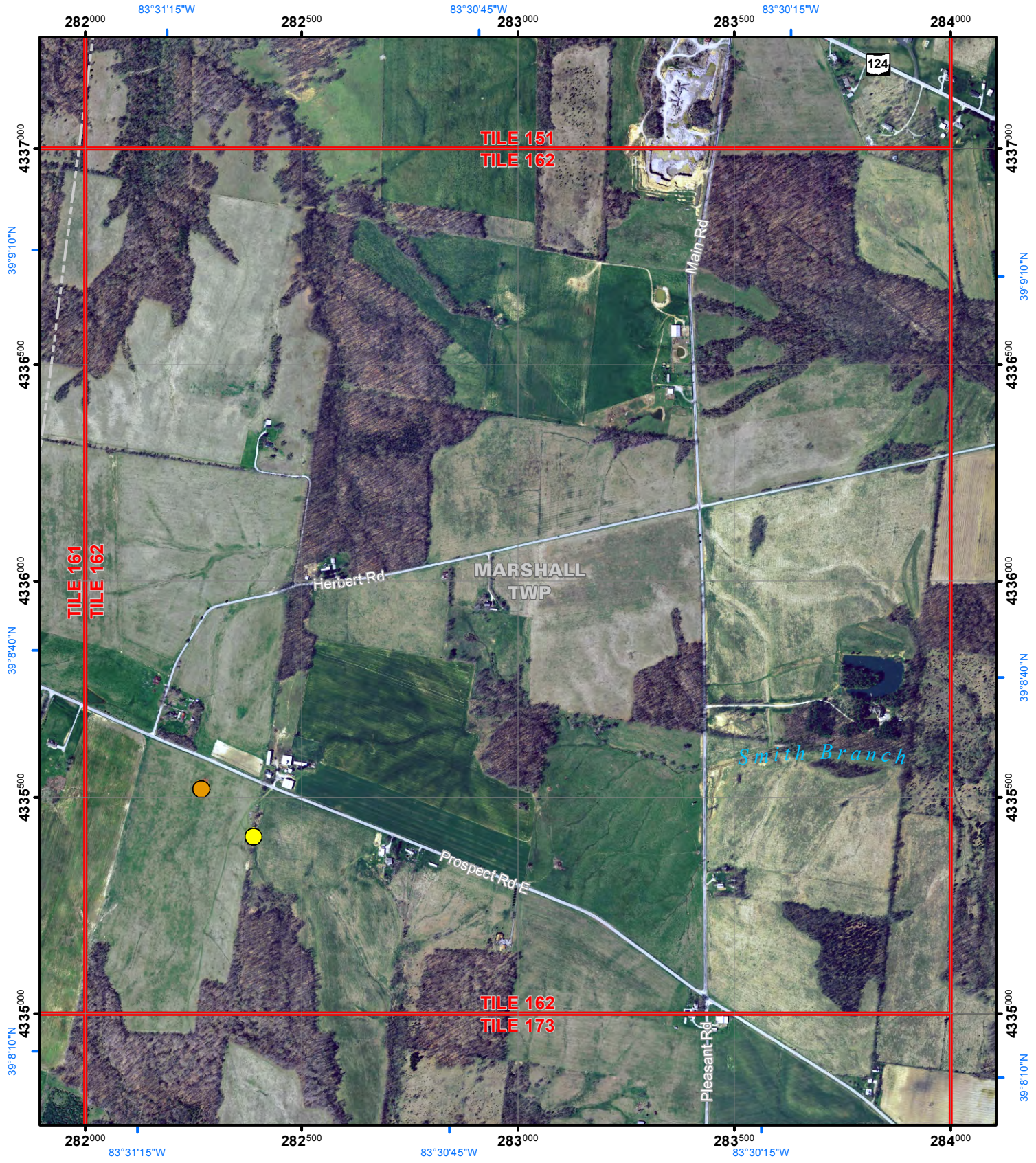
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 162



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

N W E S

KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 166

US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

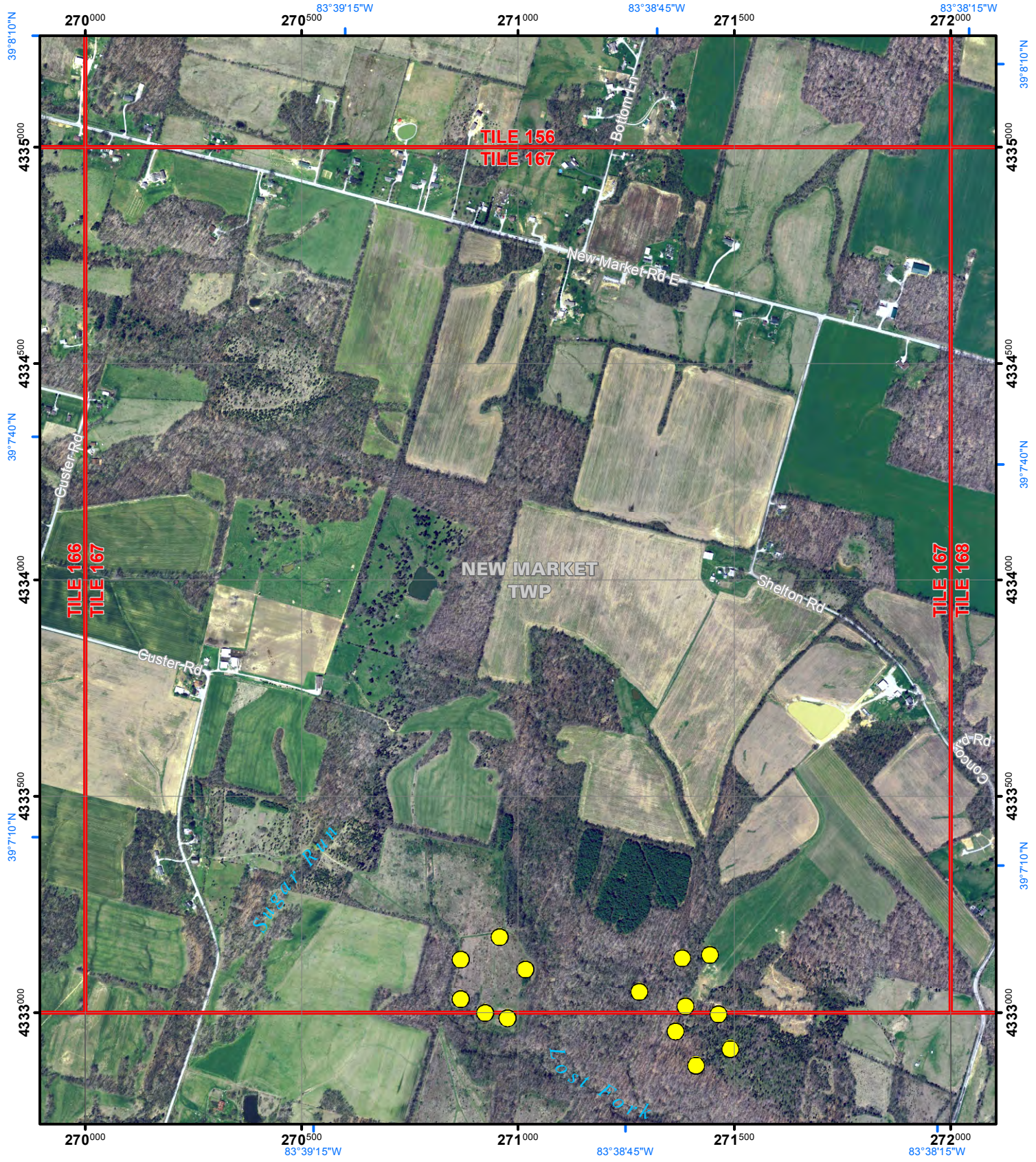
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 167



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

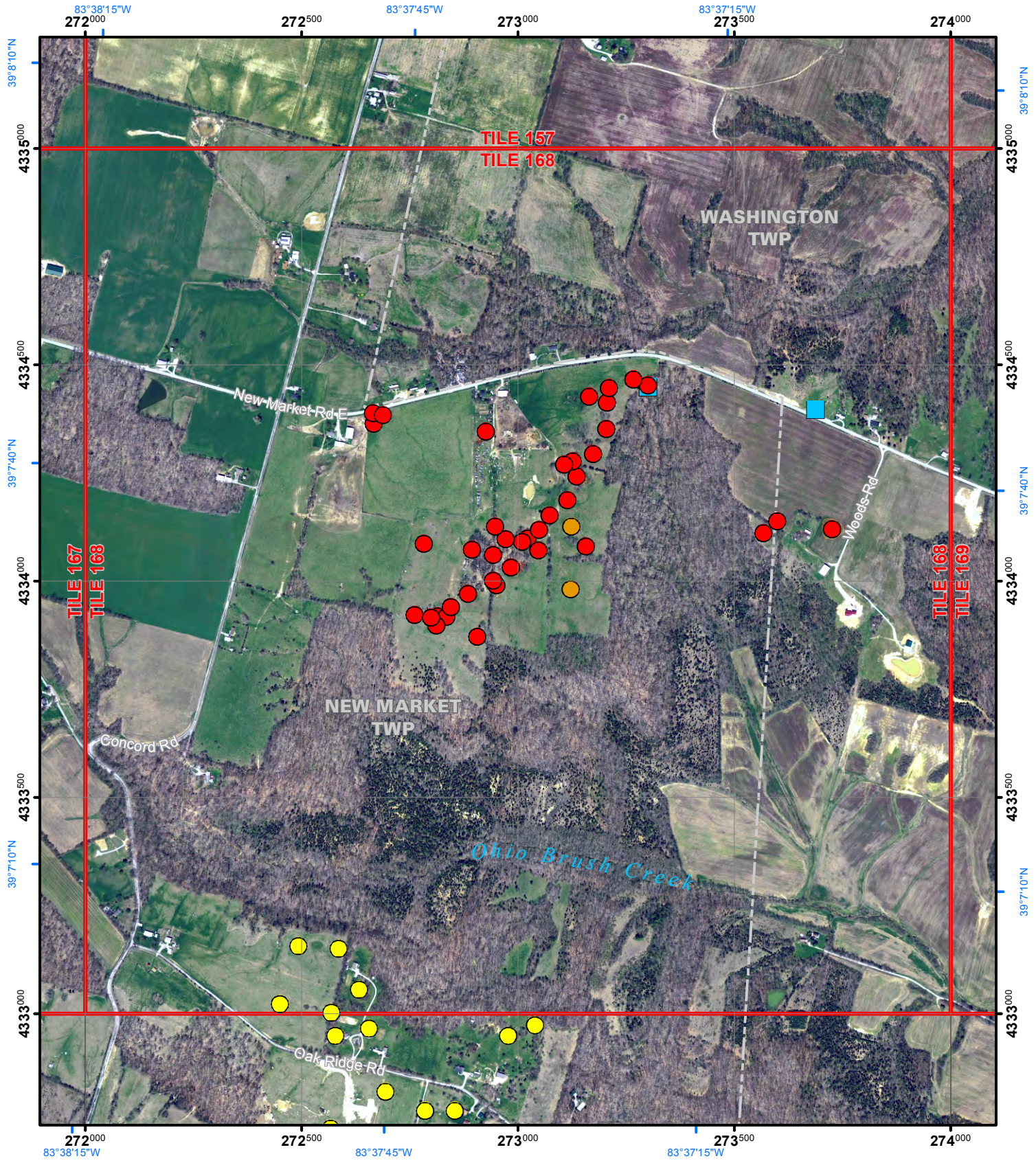
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1	5	9
2	6	10
3	7	
4	8	

Tile Number: 168



US National Grid

100,000-m Square ID: KD

Grid Zone Designation: 17S

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

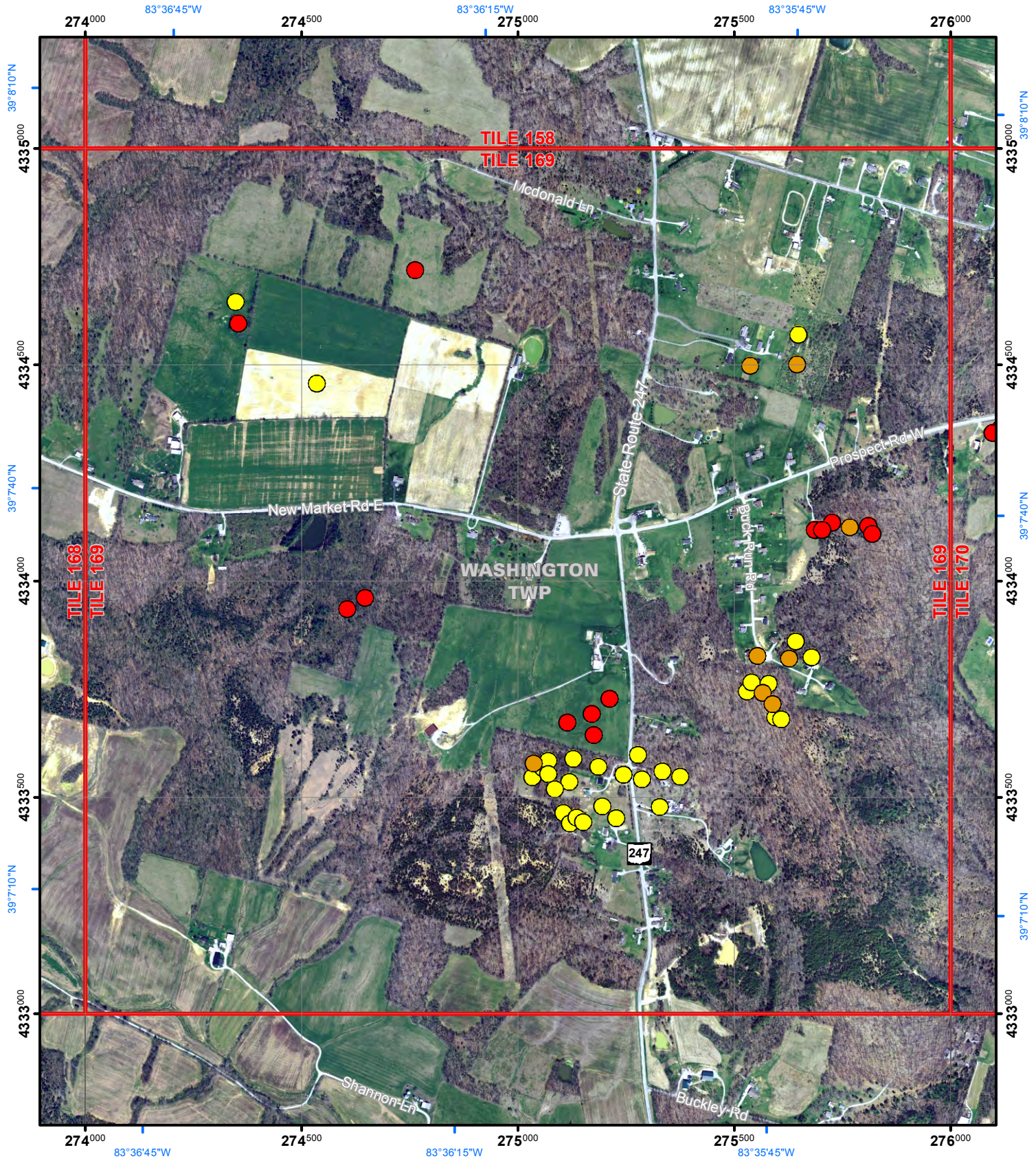
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 169



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

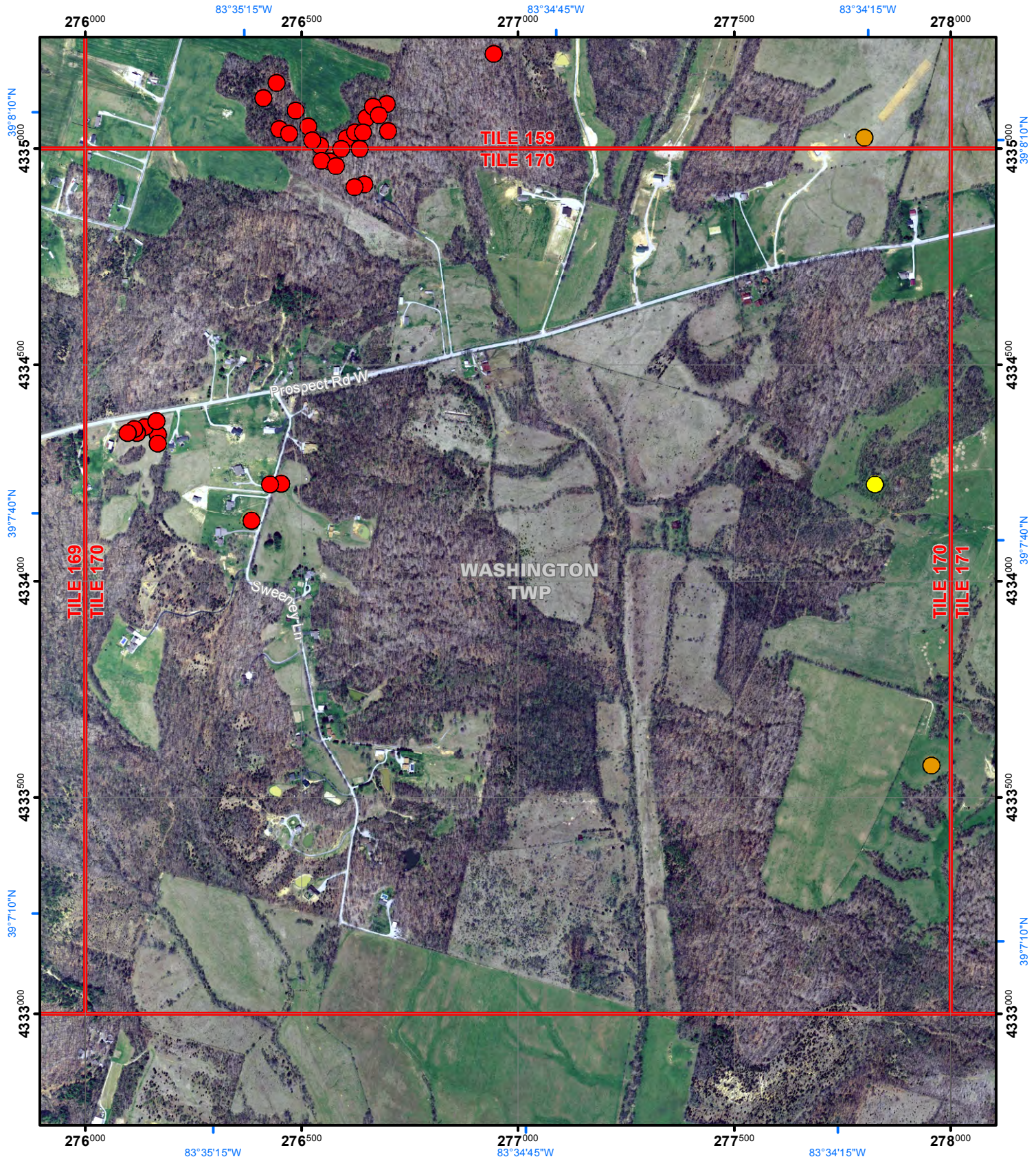
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 170



US National Grid

100,000-m Square ID: **KD**

Grid Zone Designation: **17S**

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

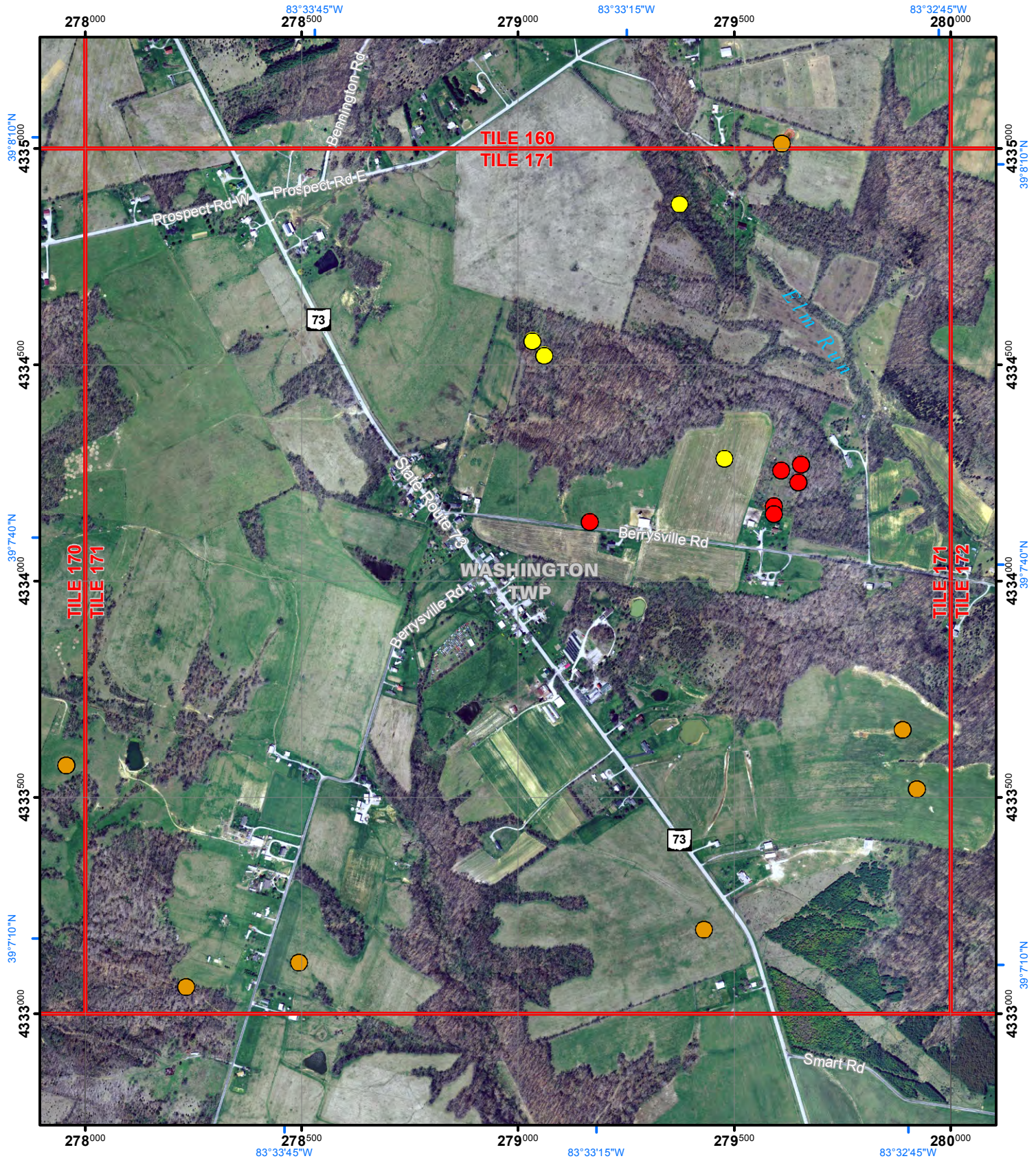
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 171



US National Grid

100,000-m Square ID: KD

Grid Zone Designation: 17S

0 — 0.5 miles

0 — 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

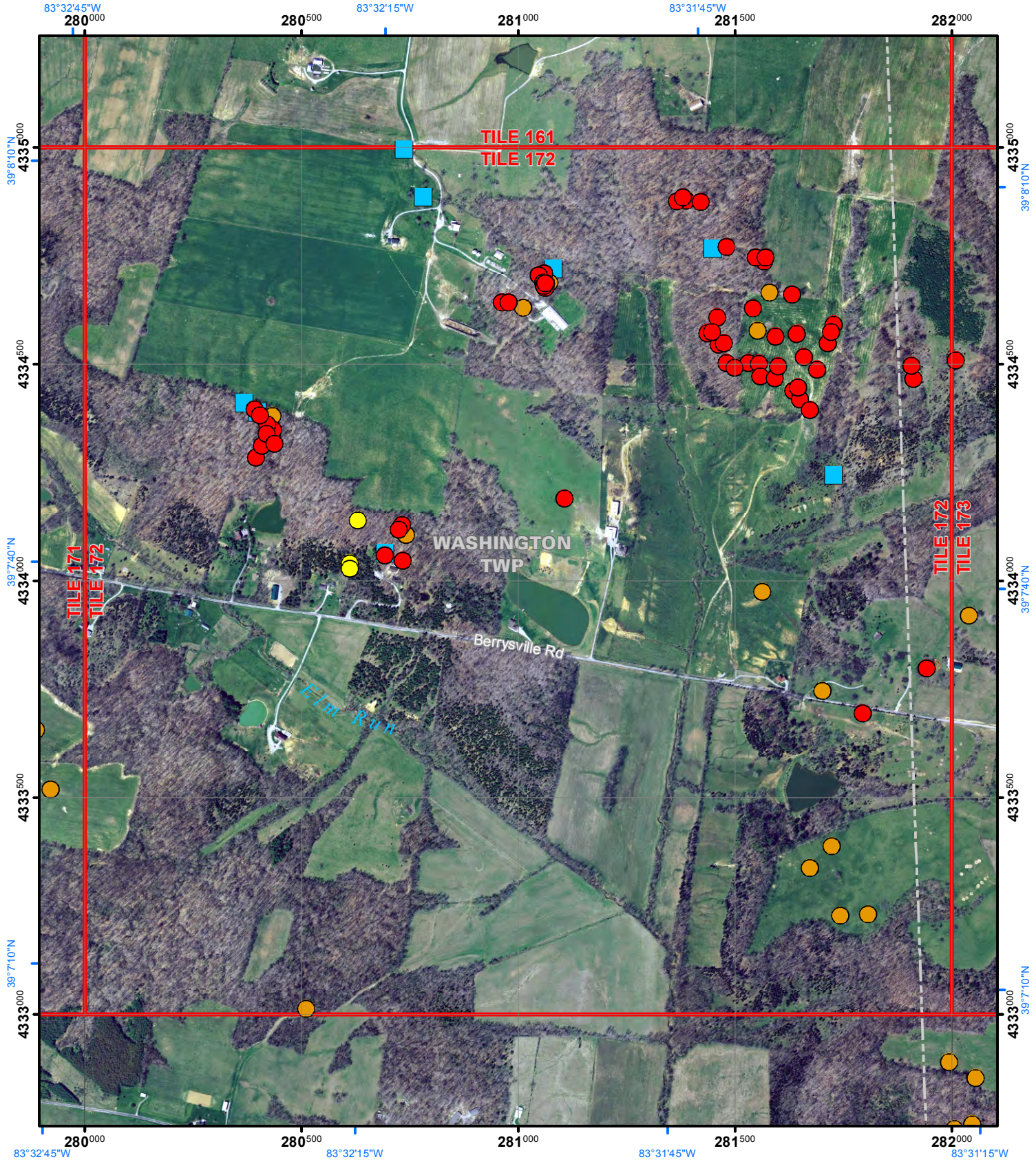
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 172



US National Grid

100,000-m Square ID: KD

Grid Zone Designation: 17S

0 0.5 miles

0 0.5 kilometers

Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

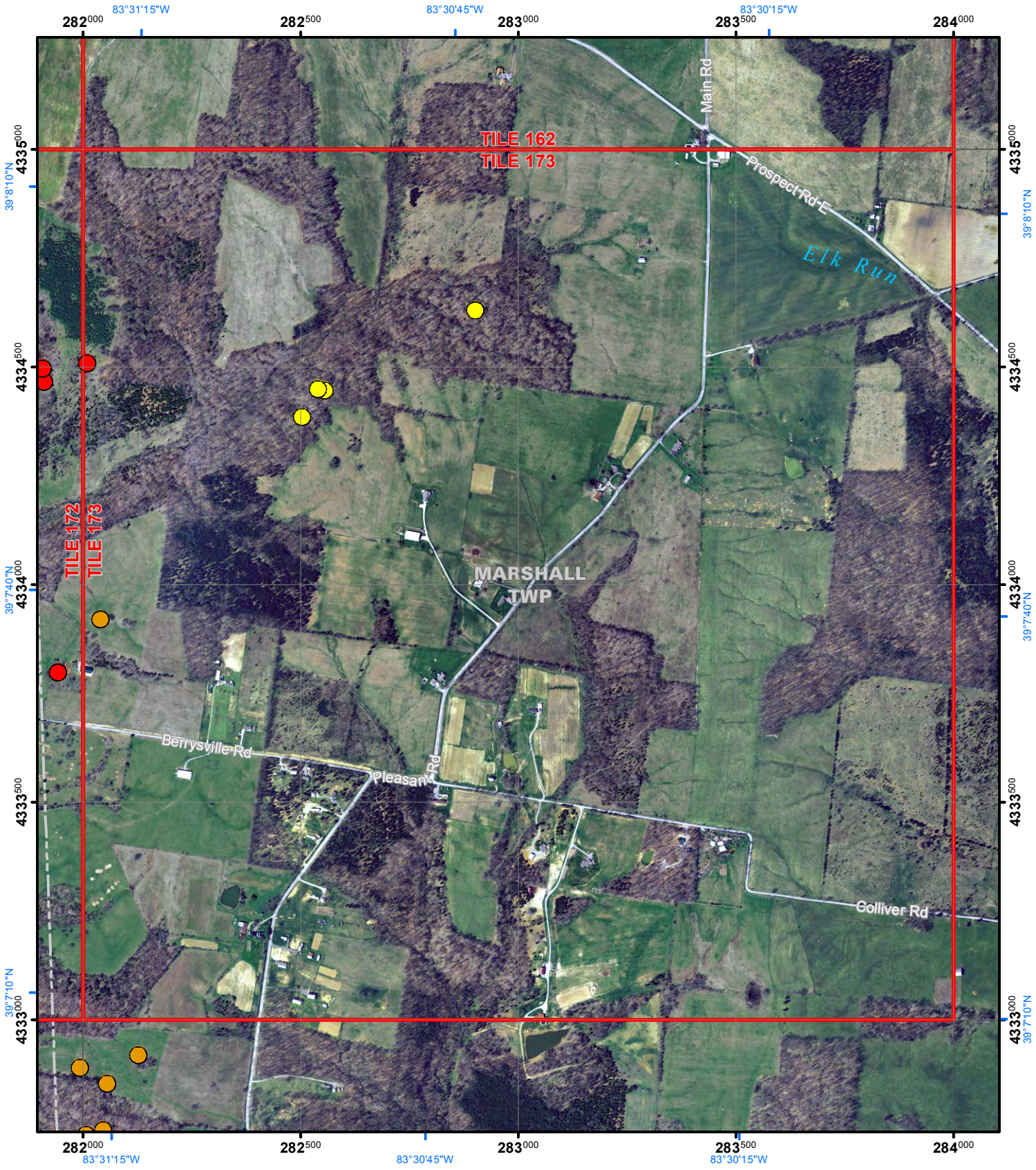
KARST FEATURES

- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet

1 2 3 4 5 6 7 8 9 10

Tile Number: 173



US National Grid
100,000-m Square ID: KD
Grid Zone Designation: 17S

0 — 0.5 miles
0 — 0.5 kilometers
Scale 1:12,000

Coordinate System: NAD 1983 UTM Zone 17N; Datum: North American 1983; Units: Meter.

KARST FEATURES
- Field verified
- Suspect - field visited
- Suspect - not visited
- Spring

DEPRESSION
Depth in feet
1 2 3 4 5 6 7 8 9 10